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NEW DEVELOPMENT PROBLEMS AND THEIR SOLUTION IN SOUTHERN CALIFORNIA OIL FIELDS

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The last eight years have been a period of marked progress in the development of new machinery and methods. The use of cable tools has almost become obsolete except on fishing jobs, sidetracking, or drilling in very shallow fields where several strings of pipe must be set. The first extensive use of the rotary method of drilling in southern California was in the development of the Montebello field, the major part of which was done during 1917–19.

New methods and advances are always accompanied by new problems. It is the engineer's place in the industry to solve these problems and remove the difficulties. One of these problems has been so to improve the well log that subsurface correlations may be easy and so apparent that all engineers will agree upon the same horizons for water shut-off depths and productive zone limits.

Although hole could be made much faster with rotary than with cable tools, the log of a rotary hole was not considered as reliable as the log of a cable tool hole. It was no unusual occurrence for a hole to be drilled through productive oil and gas formations without any good showings on the circulation ditch. Careful watch of the ditch and also of the bit cuttings which settled out of the circulation mud were usually of little help and led to confusion and erroneous conclusions, especially where the oil was of lighter gravity than 23

degrees Baumé. Most of these difficulties were overcome by the development and use of the core barrel. Up to the middle of 1921 core drilling in oil fields was only in the experimental stage. By fall of the same year it had become an established practice. Many interesting reports of how the first core sample was taken by various companies, are current. One company operating in the Huntington Beach field was drilling at a depth where, by correlation of well logs, it had been estimated the oil should be encountered. Drilling was being done only during daylight, and the resident geologist of the company watched the circulating ditch for oil showings. At times irridescent colors appeared and a very slight indication of oil was obtained by making an "ether cut" on the sand from the circulating mud. The evidence was not sufficient to convince the company officials that the oil sands had been encountered. After much discussion it was decided to run a core barrel. The single type core was used. After the core barrel was pulled from the hole and the teeth opened up, a core of clean rich oil sand 8 inches long fell upon the rotary table. The water string was cemented just above the point where the core was taken, and the hole drilled ahead 250 feet. The well came in at 600 barrels per day and flowed steadily for a year and a half until it was deepened into the lower sands. The results of the first core taken were sufficient to convince the company officials of the advantage of core sampling and since that time the company has taken hundreds of core samples. Cores are now taken in all wells by this particular company.

Core barrels are of the single and double barrel type. The single-core barrel has been described by Scott.[1] A description of the double-core barrel with comments on the advantages and disadvantages of both types is given in a paper by Elliott.[2]

The company which takes its own cores must train its drillers how to do this work. With most single-barrel type cores the circulating mud fluid is from 3 to 20 feet from the cutting edge of the barrel. If much weight is put upon the drill pipe high tempera-

[1] W. W. Scott, in "Personal Communications to A. W. Ambrose," *Bureau of Mines Bulletin 195*, 1921, pp. 22–24.

[2] J. E. Elliott, "Core Drilling with Rotary Tools in California," *Bull. Amer. Assoc. Pet. Geol.*, Vol. 7 (1923), No. 3, May-June, pp. 250–62.

tures are soon generated by the friction. These temperatures often rise above the fusion point of the formation being cored which results in badly fused cores. Some of them resemble slag from a smelter, unlike any of the sedimentary rocks of the area. The core barrels used for obtaining the samples are sometimes molded into very queer shapes, as with the teeth turned inside the barrel, leaving a smooth round surface on the end of the barrel, or with the lower part of the barrel telescoped, or wrinkled and folded like the bellows of an accordion. One core barrel made from a piece of 4-inch drill pipe had the lower 18 inches swaged down from 4 inches to $2\frac{1}{2}$ inches in diameter as neatly as could be done in any steel mill.

In almost every case the sample obtained from a fused core is so badly altered that it gives no information about the formation from which it was taken, even though the cores are 3 to 6 feet long. In the long cores the lower few inches are commonly fused to material of a glassy texture. Above this the formation is "burned" but the heat was insufficient to cause fusion. This portion of the core is usually dark in color and has a strong odor like that of exploded gunpowder. The temperature to which this part of the core was raised is sufficient to volatilize any crude oil which might have been present and even to char or burn any tar remaining. Therefore it would not show a color in ether. Above the "burned" portion, the sample is usually dry but grades upward into sand which is damp and unaltered. This uppermost part of the sample acts as a condenser and reservoir for the oil that has been volatilized from the "burned" portion below, and it can be detected easily by the common tests. Not all fused cores contain the dry and damp part of the formation at the top and when absent the sample is usually worthless.

The average driller learns how to take core samples after three to five attempts, and coring has become so universal that most drillers are now successful in obtaining good samples. One company operating in the Huntington Beach field obtained 153 cores without a failure. Another company on one of their wildcat wells took 145 cores with only eight unsuccessful attempts. Part of these cores were taken with a double-core barrel, but the majority with the single barrel type. None of the cores were fused, but

some of them had been slightly burned where taken in exceptionally hard rocks.

An admixture of circulation mud with most core samples is characteristic. Sometimes it occurs as a thin coating covering all of the sample; at other times it composes different sections of the core. This is especially true if the core barrel has been raised off the bottom of the hole while the core is being taken. The great hydrostatic pressure at the bottom of the hole causes the circulation mud to fill any cavities if the core barrel is raised and then lowered on the bottom. After examination of many core samples one learns to distinguish by certain characteristics the rotary mud from the actual formation obtained from the bottom by its manner of association with the rest of the sample, its color, texture, and composition. Moreover, the color of the circulation mud will usually be uniform through the sample and, if the formation is dark, it will be a lighter color; if the formation is light, the mud will be darker. The texture and composition of the mud is usually homogeneous, though sand grains may be scattered through it. Usually the mud is more moist than the sample of the formation, but if the sample has been heated this does not hold true.

The circulation mud in the core should not be confused with cuttings from the teeth of the core barrel. There is less chance for this to happen when a double-core barrel is used, but with the single-type barrel the distinction in some samples is quite difficult. When a sample is taken with a single-type core barrel, occasionally one or more of the teeth bend in slightly, causing a broader cutting surface, and consequently reducing the diameter of the core which can be cut. As the diameter of the core barrel above the teeth remains constant there is left an annular space between the core sample that is being cut and the inside wall of the core barrel, the thickness of this annular space depending upon the degree of bending the teeth have suffered. This space is usually filled with the cuttings from the teeth of the barrel and represent the formation being penetrated, except that it has been ground up, thoroughly mixed, and compressed under high pressure until very compact. Frequently a sample contains a small hard core, an inch or so in diameter, extending up the center of the sample which is surrounded by the cuttings from the teeth of the barrel. The entire sample is

about 4 or 6 inches in diameter and varies in length from 6 inches to several feet. A 12-foot sample examined by the writers showed 12 inches of tough brown shale at the top, the next $2\frac{1}{2}$ feet mostly oil sand with thin shale partings; and below this, $5\frac{1}{2}$ feet of hard brown shale. After the shale had been penetrated about a foot, one of the teeth on the core barrel started to bend in slightly, causing a funnel-shaped core to be cut. By the time 6 inches of hole had been made, the tooth had been bent in so that it cut a core only $1\frac{1}{2}$ inches in diameter, surrounded by cuttings. This condition was maintained until four more feet of core had been obtained, at which point the bent tooth was broken off and held in the sample. The core barrel then began to cut nearly a 4-inch core. The next 12 inches of the sample were shale, and the remaining 3 feet a clean, rich oil sand.

As the formation associated with the oil zones consists mainly of shales and sandy shales interbedded with sands with little variation, the well logs turned in by the drillers are difficult to correlate. Frequently where holes are drilled within 25 to 50 feet of another, their logs are no more alike than if they had been drilled a mile apart. This discrepancy is principally due to the amount of experience of the drillers and also to their opinions. Core sampling aids considerably in obtaining a better log, but there is yet much room for improvement. The driller's log should be supplemented by information obtained from core samples. There are also some differences of opinion among geologists and petroleum engineers as to how certain lithologic formations should be designated. A formation of shale containing disseminated sand grains of various sizes, poorly bedded and so fairly homogeneous, is called a sandy shale by some, whereas others term a sandy shale one which contains both sand and shale irrespective of their association with each other, and without regard to the various proportions of one to the other. Co-operation on the part of drillers and geologists, and a standardization of descriptive names for the various formations would aid materially in the solution of problems in correlation and structure in the fields of the Los Angeles basin.

Ethyl ether, commonly called "ether," and chloroform are the chemicals generally used in testing cores for petroleum. A positive test shows a brown color in the solvent after the sample has been

leached. The degree of intensity in color is relative and depends upon the various amounts of sample and solvent used. To make the test more quantitative in nature, the same amounts of sample and solvent should be used for all tests. Usually the heavier the oil the darker the color of the cut will be. The presence of oil in an uncontaminated core can generally be considered as positive evidence that the formation from which the sample came is oil-bearing. The absence of oil in a sample, if sandy, should not be interpreted to mean that the sand carries water. Gas sands may not show color in ether, and in fields where lenticular bedding is common sands within the oil zone not showing color may still be free from water. Sometimes both oil sand and gray, or barren, sand are found in the same sample without being separated by shale. This is indicative of, though not positive proof of, edgewater conditions.

An oil showing in a core from a wildcat well does not necessarily mean that commercial production is possible, though it has a much greater significance if the well is located on a structure favorable for the accumulation of oil. In some wildcat wells cores are taken every 20 feet when a depth has been reached at which oil-bearing formations are expected, the theory being that if a productive oil zone should be encountered one of the cores would show oil sand, and thereafter more careful testing can be made. Much activity is now being manifested in the microscopic study of core samples and it is hoped that a new method will be developed for use in correlation.

Core sampling has found general use not only in drilling wildcat wells but also in old oil fields, and in newly discovered producing areas, so that its value cannot be overestimated. It shows both the presence or absence of oil, and gives definite knowledge about shale bodies that are so important for water shut-offs and as markers for correlation. The great number of operators, both large and small, in all of the southern California fields, recognize that without the aid of core sampling, the location of cementing points for water strings and completion depths in the wells would be so different that water troubles would probably have been much more serious than they now are. Evidence obtained by core sampling should

be used in conjunction with a study of stratigraphy in all fields, for experience has shown that to rely upon the results of cores alone for shut-off points and finishing depths, is poor practice.

The high state of development of the rotary method of drilling has resulted in much deeper drilling in the loosely consolidated formations of the Los Angeles basin than was formerly possible with cable tools. Three years ago a 4,200-foot hole was considered a good depth for rotary tools. A thousand feet in depth has been added to this, and now it is a common occurrence to complete wells below 5,000 feet. The deepest hole in California, and probably the deepest rotary hole in the world, is being drilled by the Standard Oil Company at Santa Fe Springs. This well, Brownrigg-Keller No. 2, is now drilling at 7,154 feet. The 11-inch casing was cemented at 3,137 feet and the $8\frac{1}{4}$-inch casing at 4,210 feet, the latter having subsequently been cut and removed above 3,000 feet. A $7\frac{3}{4}$-inch hole has been carried to the bottom, a 4-inch drill pipe having been used since setting the $8\frac{1}{4}$-inch casing. Deep holes necessitate the setting of very long strings of pipe with several hundred feet of friction. Such practice is very hazardous and in order to prevent the pipe being frozen off bottom, it is necessary to keep the size of hole as large as possible. In order to do this, the use of 11-inch casing has been substituted for 10-inch casing. This allows a $10\frac{3}{4}$-inch hole to be made instead of one $9\frac{3}{4}$ inches in diameter, thus permitting the $8\frac{1}{4}$-inch casing to be carried to much greater depths. This new change in casing program permits a water shut-off at the top of the Bell zone in Santa Fe Springs with 11-inch casing, and a shut-off above the Meyer zone with $8\frac{1}{4}$-inch casing. A $6\frac{1}{4}$-inch casing is then used for the oil string. The large hole has the decided advantage, while being drilled, of making fishing jobs fewer and more successful. A $6\frac{1}{4}$-inch oil string also has many advantages over a $4\frac{3}{4}$-inch string, the most important among them being: (1) larger tubing can be used for pumping at great depths; (2) in wells needing cleaning out or repair work, cable tools work much better in the larger size pipe; and (3) later deepening of the hole can be done through the $6\frac{1}{4}$-inch casing without a sidetracking job. The chief objection to the use of these long strings of $8\frac{1}{4}$-inch casing as water strings above the Meyer zone is that their collapsing

pressures are much less than those for 6¼-inch casing. A string of 8¼-inch casing 5,280 feet long was successfully landed in Superior Oil Company, Swaffield No. 2 at Long Beach. The 11-inch casing was cemented at 2,776 feet, leaving 2,504 feet of friction. The use of these long strings of 11-inch and 8¼-inch pipe made it necessary to reinforce the derrick to withstand the added weight. Strings of pipe are now successfully landed and cemented that weigh approximately 100 tons. Much of the strain is taken off the pipe, and also off of the derrick, by floating the pipe in the hole. This is done by inserting a cast-iron baffle plate or a specially designed check valve between two joints of the casing very near the bottom or at the shoe. The baffle plate contains one or more small holes which only allows the fluid to enter the pipe slowly, thus absorbing much of the strain that would otherwise be upon the pipe and derrick. The check valve does not permit the entrance of any fluid from beneath and just enough is admitted at the top to keep the pipe from collapsing. These appliances are easily broken out the next time the tools are run in the hole. Besides relieving the strain on a string of pipe this arrangement has the added advantage of greatly reducing the impact if a string of pipe parts, and falls to the bottom. Drill pipe is also being floated in the hole. Besides reducing fishing jobs, floating also lengthens the life of the cable and brake bands, and reduces the wear and tear on the draw works and engine.

Other casing programs are used than the one referred to above. Many operators set stovepipe casing for one or two hundred feet. This is followed by a 12½-inch casing to about 2,000 feet, 8¼-inch to 3,800 feet, and 6¼-inch casing to depths below 4,000 feet. When the 6¼-inch casing is used at Santa Fe Springs as a water string above the Meyer zone, it means that the oil string must be 4¾-inch casing. To avoid this difficulty, attempts, more or less successful, have been made to run 8¼-inch casing to the top of the Meyer zone.

The problem of reaming a rotary hole is becoming more and more important. Some operators use a 4-way bit, others a reaming bit which is usually very long. If the latter encounters an obstruction in the hole, it is necessary to pull out the reaming bit, run in

with another bit, to clean out the bridge, and then again run in the reaming bit. Under present practice holes cannot be reamed to a size larger than the diameter of the casing through which the reaming bit is run. It is extremely important, however, where friction is great and the amount of pipe to be put in the hole is in excess of 300 to 500 feet, that the annular space between the pipe and the wall of the hole be enlarged. Two ingenious ways have been developed, namely, to turn down the collars, or to weld the pipe. If the collars have been designed properly by the steel mills, it is not advantageous to turn them down. One method of eliminating this difficulty has been to substitute 11-inch casing for the 10-inch size where a casing program with these exists. The tendency to do this has been more marked in the last six months; also the inclination to leave 12½-inch casing and substitute 15-inch and 11-inch, while not marked, has shown strength in the last year.

This condition has tempted others to secure a more satisfactory way of solving the situation. One of the best of these is the Hazard rotary under-reamer. The lowermost part of this under-reamer consists of an ordinary fish-tail bit, which merely goes ahead of the under-reamer and keeps the hole clean. This eliminates the necessity of pulling the under-reamer bit out and running in on a separate trip to clean out bridges. The under-reamer consists of two pieces of steel which are released when they pass below the casing so that they flare out an inch and a half beyond the bit, the blades being made of any desired length. The under-reamer cuts the hole an inch and a half larger than the diameter of the casing through which it is passed, thus eliminating the need of turndown collars or of welding the pipe. While under-reaming is not important when 11-inch casing is used, it would prove very beneficial when 6¼-inch is to be run through 8¼-inch. The under-reamer reams a hole much more rapidly than the ordinary reaming bit, so that it promises to find its place in the industry along with many other innovations that have come within the last two years.

Besides the advantage of making hole fast, the rotary method of drilling has also the advantage of protecting the oil and gas formations while drilling through them. This protection is afforded by mudding the formations in the regular process of drilling with

the subsequent use of a sufficient amount of cement to extend well above the shoe of the cemented string. An excellent example of this protection is found in two wells in the Huntington Beach field. Number 1 well was drilled to 2,640 feet. A successful water shut-off was obtained on the 10-inch casing, cemented at 2,217 feet. The $8\frac{1}{4}$-inch oil string, including 421 feet of $7\frac{5}{8}$-inch McEvoy screen, was landed at 2,638 feet. The well was completed August 15, 1921, flowing 1,170 barrels of 25-gravity oil, cutting .05 per cent. One week later No. 2 well came in with an initial production of 207 barrels of 22.4-gravity oil cutting .3 per cent. The water shut-off in this hole was made by cementing the 10-inch casing at 2,735 feet, using 500 sacks of cement. The $8\frac{1}{4}$-inch oil string including 111 feet of McEvoy screen was landed at 2,831 feet, this being one foot off bottom. Number 2 well is located 280 feet northeast of No. 1, and is approximately 70 feet lower on the structure. As the water string in well No. 2 was cemented below the relative bottom of No. 1, it allowed the full head of the top water to be exerted upon the formations from which well No. 1 was producing. The effectiveness and value of mudding, with the subsequent use of cement in sufficient quantity, is evident when it is learned that after two years well No. 1 yields 338 barrels of 24.5 gravity, with a cut of only 1 per cent. Well No. 2 has now a production of 65 barrels per day of 13-gravity oil, cutting 17.2 per cent water and emulsion. The benefit of mudding and large amounts of cement is also apparent from a study of the production data (Table I) from eleven wells in the Santa Fe Springs field which are producing from the Bell zone, although this zone has been "punched" full of holes in the rush to the Meyer sands. An intermediate water sand occurs between the two zones over the greater part of the area and, as no casing has been cemented immediately above this water sand, it is apparent that the only protection afforded the Bell zone against this water is that of the mudding and the cement. Three of these wells which have been on production for a year or more still show a cut of only .1 per cent. The other eight wells which have been producing from 6 to 10 months all show a cut of less than 1 per cent.

There has been considerable discussion among operators and the State Mining Bureau about the value of additional or supple-

mental mudding. This supplemental mudding is required by the State Mining Bureau. Some operators concur with the Bureau, while others believe that the hazard and risk accompanying the operation more than equal any benefits that might be derived from it.

The relatively short time in which a well can be drilled and completed is due not only to a faster rate of drilling, but also to the introduction and use of chemical substances for hastening the setting of cement. Several of these chemicals are on the market.

TABLE I

PRODUCTION DATA FROM WELLS OBTAINING OIL FROM THE BELL ZONE IN THE SANTA FE SPRINGS FIELD, CALIFORNIA

WELL	1922				1923									
	September		November		January		March		May		July		August	
	Prod.	Cut	Prod.	Cut	Prod.	Cut	Prod.	Cut	Prod.	Cut	Prod.	Cut	Prod.	Cut
	Bbls.	Per Cent	Bbls.	Per Cent	Bbls.	Per Cent	Bbls.	Per Cent	Bbls.	Per Cent	Bbls.	Per Cent	Bbls.	Per Cent
No. 1..	.....	....	.....	....	.....	....	1,909	.5	1,225	.5	926	.5	70	.2
No. 2..	2,821	.1	1,770	.1	1,229	.1	902	.1	458	.1	510	.1	410	.1
No. 3..	.....	....	2,055	.1	1,437	.1	954	.1	549	.1	558	.1	551	.1
No. 4..	.....	....	.....	....	3,074	.1	2,209	.1	1,131	.5	360	.5	390	.1
No. 5..	.....	....	1,102	.1	750	.1	456	.1	395	.4	391	.1	381	.0
No. 6..	.....	....	1,147	.1	660	.1	487	.6	532	.4	163	.8	189	.9
No. 7..	1,978	.0	959	.1	540	.1	389	.2	438	.1	535	.1	525	.1
No. 8..	.....	....	912	.0	491	.1	393	.1	485	.1	557	.1	532	.1
No. 9..	.....	....	900	.2	375	.2	Off	....	799	.1	740	.1	600	.1
No. 10.	1,081	4.8	Off	....	532	.1	650	1.7	824	.1	792	.1	1,050	.1
No. 11.	.....	....	.....	....	.....	....	1,542	.2	855	.2	498	.1	694	.2

The results of 86 cement jobs on one company's wells in the Huntington Beach and Santa Fe Springs fields are given in Table II. A total of 244 days were required for the 61 jobs where the chemical was used. If the chemical had not been used, it would have required a total of 854 days of waiting for the cement to harden. It will also be noted that the per cent of failures necessitating the use of an extra string of pipe was 12 per cent on jobs without chemical and was only 4.9 per cent on those where chemical was used. This higher percentage of failures where chemicals were not used is not due entirely to the absence of the chemical. These failures occurred in the earlier stages of development of the fields when the drilling

technology in this field had not been so highly perfected. The table is given mainly to show that the time element is the big factor with chemically treated cement and not that it results in more dry jobs. It is also apparent that with the use of chemically treated cement considerable time is saved in plugging. Often making possible a completion in from one-third to one-half the time that would otherwise be required. From present indications, it appears that chemically treated cement will be just as durable as the non-treated cement.

Water troubles are probably the most serious obstacles that have to be overcome in oil-field operations. In new areas, where

TABLE II

DATA ON CEMENTING WELLS IN THE HUNTINGTON BEACH AND SANTA FE SPRING FIELDS, CALIFORNIA

	Chemical Reagent Added to Cement	Cement Without Chemical Reagent
Total number of cement jobs	61	25
Number of failures	6	5
Successful re-cement jobs	1	0
Failures because of water below shoe	1	1
Failures because of bad casing	1	1
Number of extra strings of pipe needed because of failure of first string to shut off water at top of the zone	3	3
Average number of days required for cement to set	4	14

the exact depth or position of a water sand with respect to the productive oil sands is not known, flow tests are proving a very successful means of locating the water. Briefly described, these tests are made in the following manner. A water string is cemented and a shut-off obtained just above the point at which testing is to begin. The well is then drilled ahead 50 feet or more depending upon the amount of formation to be tested. Without putting in a perforated liner or oil string, tubing is run in the well and kept far enough up in the water string to prevent heaving sand or mud from sticking it. The well can then be washed between the tubing and the casing by circulating clean water and later bailed or swabbed through the tubing, or the bailing and swabbing may be done without

washing. This is continued until the well begins flowing or until it is demonstrated that water has been encountered below the shoe of the cemented casing. An analysis of the water from the bottom to determine its soluble chloride content is usually made. Such analyses help to determine the presence or absence of an interfering water. If the well flows, it should be allowed to do so long enough to prove that no water is present in the zone being tested. This may require three days, more or less. Cuts and gravities should be taken upon the oil as the data secured are often a great help in correlating, as in some cases the gravity of the oil is one of the most reliable kinds of information available to correlate formations. After the presence or absence of water has been established, the well can be easily "killed" by circulating mud through the tubing. The tubing is then pulled and drilling resumed, if desired.

Flow tests have also been found to be of great value in testing water shut-offs where oil and gas are present in such quantities that the results obtained by ordinary bailing tests are not conclusive. A flow test made at this time often establishes without a doubt the presence or absence of water, and necessary measures for correction can be taken more advantageously at this stage than after the oil string is run in and the well completed.

The problem of locating water in a well after it has been put on production is usually quite difficult and requires patience and long testing. There are three methods by which the point of entrance of the water into the well may be determined. The test most used and probably the best is known as the sand test. This is made by filling the hole, in stages, with screened beach sand. Pressure tests are made by packing off between the water string and the oil string and applying a pump pressure on the inside of the oil string. The principle upon which these pressure tests are made is that a sand carrying a low head water will take water when pressure is applied to it. Some operators do not use the pressure tests, but fill the hole with sand up beyond the top of the perforations. The common method of putting the sand in the well is to dump or shovel it in at the casing head and allow sufficient time for it to settle through the fluid column. After the sand has settled, the top of the sand bridge is located with a bailer and a bailing test

made to determine the condition of the pipe. The sand is cleaned out in stages either by circulating it out with mud fluid by the use of tubing or drill pipe, or it may be bailed out. The well fluid is bailed down for each successive sand bridge, and allowed to stand a given time, after which the rise in fluid is noted. This process of cleaning out the sand in stages followed by a bailing test is continued until the sand is lowered to a point where it can no longer exclude the water. The test is usually repeated to verify results and to get a closer check on the point at which the water is entering the well. The Pearce water in the lower zone of the Huntington Beach field was located by means of this test. The Miley-Keck No. 31 water, which is also an intermediate water in the Lower or Ashton zone of the Huntington Beach field, was located by the flow test method described above.

Two other methods used for locating water are the salt concentration test and the mud fluid test. Neither of these tests is so reliable or efficient as the two methods just mentioned. The salt concentration test is made by washing the hole with fresh water and then bailing off the top of the fluid to permit the entrance of salt water into the well. Samples are then taken at various depths in the hole and analyzed by titration for soluble chlorides. The results of the test are based upon the assumption that the maximum chloride concentration will be found opposite the water sand.

The mud test is made by first filling the hole full of thick rotary mud and then bailing from the top of the mud until considerable water has entered the well. Samples are then taken at various depths. Almost clear water will be found at the point opposite the water sand, whereas immediately below and above this there will be the thick rotary mud. It is advisable to repeat the test to verify previous results. This and the salt concentration test may be made quickly and at little expense.

The loose unconsolidated condition of some of the oil sands in the Los Angeles fields has always caused more or less trouble for the production man. The common practice of perforating casing in the hole has now passed. Various kinds of screen and strainer pipe are being made as the result of an effort to control the sand troubles. The most common kinds are the McEvoy strainer, E. M. Smith or

Emsco screen, and Layne & Bowler screen; torch slotted pipe is also being used to some extent. The shape and size of the openings are similar in the different makes of pipe. Experience has taught that best results are obtained by placing the openings in clusters of three to five holes each, the holes, or slots, averaging about 1 inch in length and varying in width from 0.06 to 0.14 inch, or even larger. They are wider on the inside than on the outside, thus allowing any sand particle that enters the slot to pass completely through and be carried out with the oil. The width of opening is governed by the size of sand grains and is determined by experience in any particular area.

The use of screen pipe alone is not sufficient to control sand troubles; but with the aid of the recently developed method of controlling the flow of the well by small changes in the flow nipple, or bean, the annoyance caused by loose sand has been greatly reduced. Flow beans are made in sizes varying only $\frac{1}{64}$ inch in diameter and so universal has their use become that field production men speak of the size of the bean according to number, representing variations in diameter of $\frac{1}{64}$ of an inch. Flow connections are so "rigged up" that at least two flow lines run from the well. Each flow line is equipped with a bushing so that the flow bean can be changed readily. Control gates are so arranged that the flow of oil may be quickly changed from one line to the other when a new flow bean is being inserted. A change in the size of the flow bean from $\frac{1}{64}$ to $\frac{3}{64}$ of an inch is in many cases sufficient to reduce the cut of sand from 2 or 3 per cent to less than 0.5 per cent and convert the well into one with a steady flow without danger of being sanded up. The use of small variations in the sizes of flow beans permits flowing wells to produce at their maximum without allowing the gas to "break through."

A well flowing through tubing is more sensitive to small changes in the size of flow beans and can be kept under a more perfect control. The size of tubing to be used depends upon the rate at which the well is to produce, the greater the flow of a well the larger the tubing. Wells that produce more than 7,000 barrels per day will probably do best through a $6\frac{1}{4}$-inch pipe. For wells producing from 3,400 to 7,000 barrels, $4\frac{1}{2}$-inch tubing is the best size; for those producing

from 1,500 to 3,400 barrels, 3-inch tubing is preferable; and $2\frac{1}{2}$-inch tubing is best suited for flowing wells with production less than 1,500 barrels per day. There are no well-defined limits in size for the use of tubing so that the above values are only approximate. Besides the flow, the size of the oil string is the other determining factor in selecting the size of tubing. For instance, if the oil string is $4\frac{1}{2}$-inch casing and the estimated initial flow of the well is between 3,400 and 7,000 barrels, it would not be wise to try to make the well produce through smaller tubing, as the $4\frac{1}{2}$-inch casing is the best size for such a production. If the oil string had been $8\frac{1}{4}$-inch casing then the use of $4\frac{1}{2}$-inch tubing would have been the proper selection.

During the summer of 1923, the curtailment or prorating of production of flowing wells has been necessary. This has had a very beneficial effect in an entirely unexpected way. With wells flowing wide open there is always a wastage of gas. At least one-third of the production of the three large fields is in the hands of new and inexperienced operators. These men have such small tracts and so few wells that by the time they develop the experience which the large operator already has, or develop by studying individual characteristics of the fields, the small operator has no more wells on which to apply his experience. Being anxious to get all the oil that he can, he is prone to flow his well to the limit. In a general way, a barrel of oil is accompanied by a flow of 1,000 cubic feet of gas, though in some instances this is as much as 3,000 cubic feet. This represents the waste of the gas necessary to lift the oil. Because prorating has been in effect, anxiety on the part of an operator to get all his oil has been held in check and the gas has not been wasted. Although state law gives the State Oil and Gas Supervisor power to regulate the waste of gas in the California fields, any attempt on his part to meet this situation would prove futile. It would be necessary to station a man at every well to watch the flow of gas at all times. Prorating has had the practical effect of accomplishing this very purpose, and it is unfortunate that it will not continue during the declining life of the fields, for as the gas pressures become less, it is probable that the amount of gas flowed with the oil will increase.

DISCUSSION

J. E. Elliott: The determination by the use of the core barrel of the source of water immediately after a well has been cemented, and a test made indicating that water is leaking into the hole, is an important aid in production. There are two possible sources for such water, one from behind the casing, due to a faulty cementing job, or from a formation below the point of cementing. This question can often be settled by taking a core directly below the cementing point. If shale is encountered, it is evident that the water is coming from behind the casing, and a re-cement job is necessary. If sand containing no oil is extracted, it is almost as certain that this is the source of the water, and that a new string of pipe is essential.

An example of this occurred at Huntington Beach. A well cemented at approximately 4,400 feet was bailed at around 2,000 feet, and the fluid started to rise, indicating that water had broken in. The question of whether the water was coming from the sand below the shoe or from around the casing was settled by extracting the core. This core was a sand heavily impregnated with oil, indicating that the source of water was due to a faulty cementing job. After being re-cemented, this well became one of the large producers at Huntington Beach.

Another point to be emphasized is the use of the core barrel for the detection of edge water. One of the best examples coming to our attention was at Santa Fe Springs where it was desired to ascertain where the edge water in the Bell sand was. One hundred feet of continuous coring showed that in the lower fifty feet were sands containing no oil. I recall one particular core of sand three feet in length that had four distinct changes. The upper few inches was comprised of very rich oil sand below which was a similar sand showing no evidence of oil. Directly below that were eight or nine inches of oil sand followed again by a sand not impregnated with oil. At this point, the company decided to make a test, and this test confirmed the conclusion made from the core samples that edge water had been found. Similar instances at both Santa Fe Springs and Long Beach in which coring has been the means of determining the location of edge water could be enumerated. In many of these instances, this sort of testing has resulted in eliminating considerable water trouble that otherwise would not have been detected until too late.

SUBSURFACE STRUCTURE OF EASTERN KENTUCKY[1]

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University of Kentucky

Geologists who are familiar with the structural geology of eastern Kentucky know that certain rather peculiar subsurface conditions exist which directly affect prospecting and development work and are, therefore, of vital importance. There is no literature which tells of these conditions. This article presents some results of a study of the structural conditions obtained by compiling a large number of maps, and by plotting data from a great many well records upon a suitable base map.

Practically all of eastern Kentucky has been mapped topographically. Most of the surface structural geology has been worked out, either by the Geological Survey or by oil companies. However, each map covers only a small part of the region under consideration, and several different scales have been used. The author has combined some seventy of these maps to make one map with a horizontal scale of 1 inch equal 2 miles, and a structure contour interval of 20 feet, which shows the geologic structure of outcropping formations over an area 50 miles across.

Next, certain data from one hundred well logs carefully selected from lists amounting to over 1,400, published by the Kentucky and West Virginia Geological Surveys, were plotted upon this base map. Only those well records were used that were accurately located, that gave casing-head elevation, and in which the true sea-level elevation of the Ohio black shale (Devonian black shale), the "Big lime" (Mississippian) and the Fire Clay coal could be

[1] This article is a synopsis of a thesis prepared during the spring of 1923 at the University of Kentucky. The thesis has been greatly condensed but the main points are herewith presented. The author has made use of the various State and United States maps and publications. A few maps and other data were obtained from oil companies. Some very valuable information and suggestions have been received from several geologists familiar with this field.

determined. The Fire Clay coal, which is probably the Lower Mercer or No. 4 coal and is near the top of the Pottsville, is a remarkably persistent and easily recognizable horizon throughout eastern Kentucky, and is the horizon upon which most of the surface structure has been calculated (Fig. 1). In many places its elevation is higher than that of the well casing-heads, that is, it

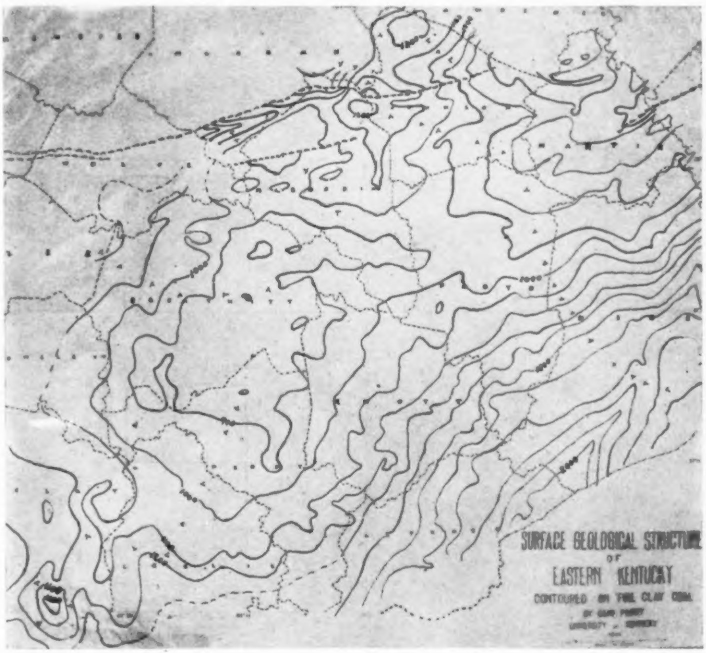

FIG. 1

crops out on the hillsides above the wells and hence does not show in the well record.

With all these well-log data on one sheet, it was a simple matter to calculate the number of feet between any of the three mentioned horizons. This was done and a convergence map showing the interval between the Ohio black shale and the Fire Clay coal was constructed. The most remarkable features of this conver-

gence are its uniformity toward the northwest, and the enormous amount of 2,000 feet in about 40 miles.

The thinning is practically all in the Pottsville series and is apparently rather uniform throughout. As proof of this, the Lower Elkhorn coal is 240 feet closer to the Fire Clay coal in the northern part of Floyd County than it is in the southern

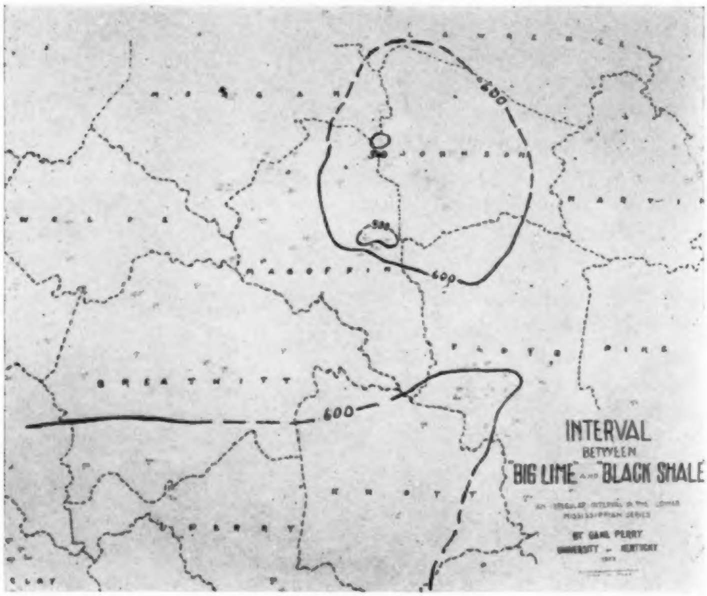

FIG. 2

part, according to James Hudnall, of the Kentucky Geological Survey.

A part of this great convergence is in the Mississippian series. Intervals between the "Big lime" and the "black shale" (Fig. 2) vary irregularly between about 450 feet and 800 feet, being thinnest at the common corner of Morgan, Johnson, and Magoffin counties, and in the southwest part of Floyd County. Measurements of the thickness of the Big lime show that where the thickness of limestone is least, there is also a corresponding decrease in the

distance between the top of the Big lime and the top of the black shale. Charles Butts, in his report for the Kentucky Geological Survey on the Mississippian of eastern Kentucky, states that the top of the Big lime is an erosion surface and mentions an erosion channel in the Big lime filled with Pennsylvanian sediments at Hiedleburg along the Kentucky River as one evidence. The

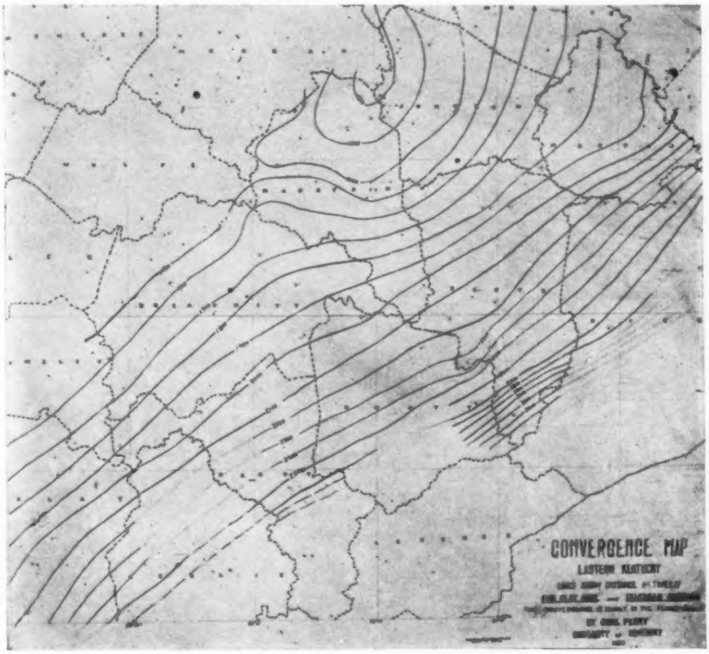

FIG. 3

conclusion reached by those who have studied the subsurface conditions of the Big lime is that there certainly was pre-Pennsylvanian, post-Mississippian folding, and that those areas where the Big lime–black shale interval (that is, the total thickness of limestone) is least, mark areas of pre-Pennsylvanian anticlinal folding. Incidentally these areas have proven to be rich oil fields, even though they fail to coincide with surface anticlinal structure within

the Pennsylvanian formations. It is probable that the Mississippian horizons are nearly parallel to those of the Devonian.

From a map of the surface structure and a convergence map (Fig. 3) between the surface horizon and some deeply buried horizon, the structure of the latter may be calculated. The convergence

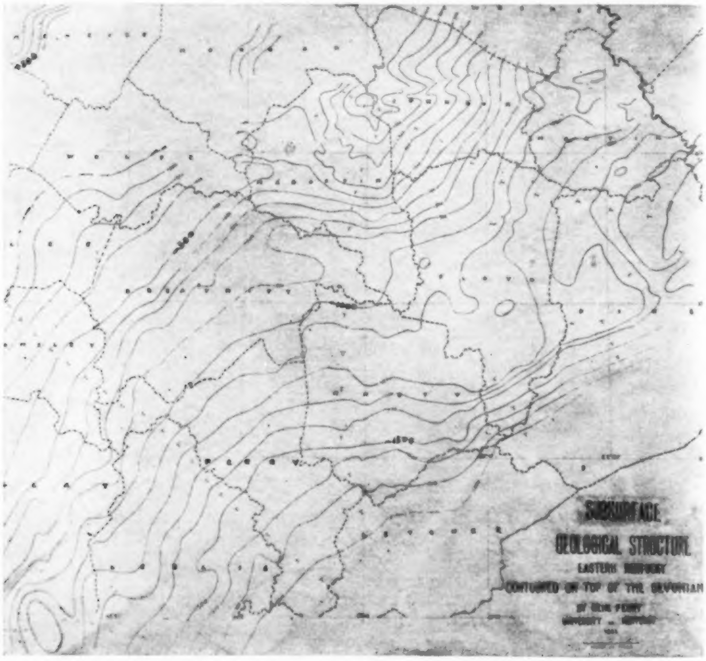

FIG. 4

map is superimposed upon the surface structure map, and at every intersection of the surface structure contours with convergence lines, the amount of convergence is subtracted from the elevation indicated by the structure contours. This gives a great number of new elevations on the deeply buried horizon. Using these new elevations, its true structure can be determined.

The subsurface structure map on the top of the black shale brings out one of the most important and interesting features

of eastern Kentucky structure (Fig. 4). This feature is the constant and fairly uniform southeast dip of the Devonian surface. In Mennefee County the black shale is 800 feet above sea-level. From here the shale dips to the southeast more or less continuously, until in Letcher County it is 1,700 feet below sea-level, thus forming a great monocline over 50 miles across.

Referring to the surface structural map, it is seen that the Fire Clay coal, which has an elevation of 1,200 feet above sea-level in western Breathitt County, sinks to 800 feet elevation in eastern Breathitt and then rises to over 2,000 feet elevation in Letcher County, and forms the well-known eastern Kentucky geosyncline. From this it will be seen that the dip of the black shale (or Devonian surface) is opposite to that of the Fire Clay coal (or Pennsylvanian formations) throughout Floyd, Pike, Knott, Perry, Leslie, and parts of Breathitt and Letcher counties. Where the surface structure forms a geosyncline the subsurface structure is monoclinal. Furthermore, the southeast dip of the black shale is about equal in degree to the northwest dip of the Fire Clay coal in exactly the same area. Drilling has not gone deeper than 1,700 feet below sea-level in southeastern Letcher or Pike counties. Whether or not the Devonian reverses is not known. It probably does.

Recognition of these subsurface structure conditions should be of the very greatest value in prospecting for oil and gas in eastern Kentucky. It is advisable that in the future oil prospecting in eastern Kentucky be governed entirely by subsurface structure. The determination of this subsurface structure will necessarily involve the use of surface structure in connection with data obtained from well records, preferably in the form of convergence maps.

THE CORRELATIVE VALUE OF THE HEAVY MINERALS

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The microscopic study of well samples has proved of value in the correlation of sediments, and considerable interest is being manifested by operators and geologists on this subject.

Up to the present time, most attention has been paid to the study of the minute fossils, particularly the Foraminifera. While the correlative value of microscopic fossils is recognized to be great, the minerals composing the sediments may offer criteria where these fossils are absent, or may be of particular value in correlating between narrow vertical limits, where the fossil species have too wide a vertical range. Such detailed correlation is necessary in the drilling of an oil field, where casing must be landed, water shut off, and wells finished in stratigraphic uniformity.

Illing[1] in Trinidad, Goldman[2] in Texas, and Milner[3] in England, have applied the study of the mineral components of strata to their derivation and correlation.

For the purpose of investigating the relationship between sedimentary beds and their mineral composition, a research has been conducted under the supervision of the department of mining at Stanford University by Ralph D. Reed and the author. This research has sought to ascertain whether or not comparison of the minerals composing the individual beds of a sedimentary series would serve to differentiate one bed from another.

Up to the present time the localities studied are the western part of Ventura County, California, and the region south of Coalinga field, California.

[1] V. C. Illing, "The Oilfields of Trinidad," *Proc. Geol. Ass.*, Vol. 27 (1916).

[2] M. I. Goldman, "Lithologic Subsurface Correlation in the 'Bend Series' of North-Central Texas," *U. S. Geological Society Paper 129-A* (1921).

[3] H. B. Milner, *An Introduction to Sedimentary Petrography* (1922).

The Fernando beds in the region of Ventura River show a remarkable homogeneity of texture, being composed of alternating thick beds of sandstone and thin beds of shale, without distinctive marker beds. Correlation in this field has always been a difficult problem. In making a microscopic study of the minerals present in some beds and absent in others, samples were taken every hundred feet from the axis of the Ventura anticline down Ventura River to its mouth (Figs. 1–12). Examination of these samples showed that the amphiboles and epidote have the most noteworthy variation in abundance. Five or more samples in vertical sequence may contain large amounts of epidote in the heavy residue; the next five or more samples, perhaps, contain almost no epidote but an abundance of green and brown amphibole, and these may be followed by another sequence rich in epidote. In the whole section, one sequence of two or three samples was rich in glaucophane, this mineral being rare or absent elsewhere. There seemed to be a gradation from one sequence to another with respect to a certain mineral. For instance epidote might be absent from a number of samples in sequence, then it would occur sparingly, increase to a maximum, and finally die out again, the amphiboles coming in as the epidote decreased. Further sampling at closer intervals is necessary to demonstrate the relation of mineral assemblages to stratigraphic sequence, but the suggestion is strong that there are zones of certain heavy minerals and other zones of other heavy minerals.

In the region south of Coalinga it was found that the Tejon (Eocene) beds can readily be differentiated, microscopically, from the overlying Miocene formations. The Miocene beds contain abundant minerals of the amphibole group, while the Eocene beds contain almost none. This is probably due to the fact that the Eocene beds were derived from the Cretaceous sediments, in the process of reworking which the less resistent amphiboles were destroyed. This amphibole criterion for the Miocene was established by examination of a large number of samples taken along the contact. The Monterey-Temblor sandstone, constituting the base of the Miocene was sampled at short intervals for about 20 miles along its strike. No lateral variation of the mineral assemblages was detected at this horizon, and abundant amphibole was found in every sample examined, whereas the Eocene below it contained none.

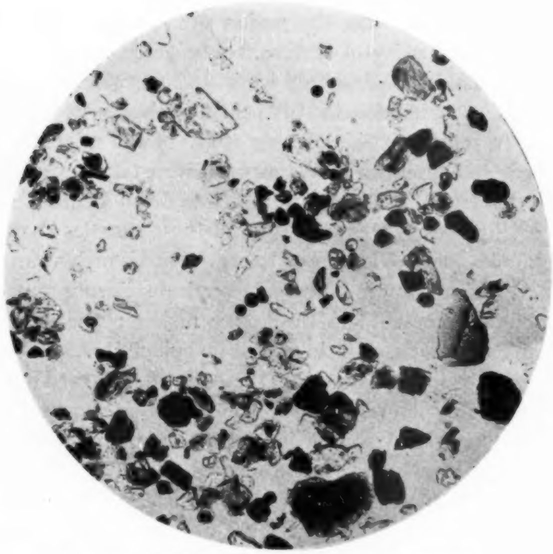

FIG. 1.—Cleaned but unclassified material (× 25)

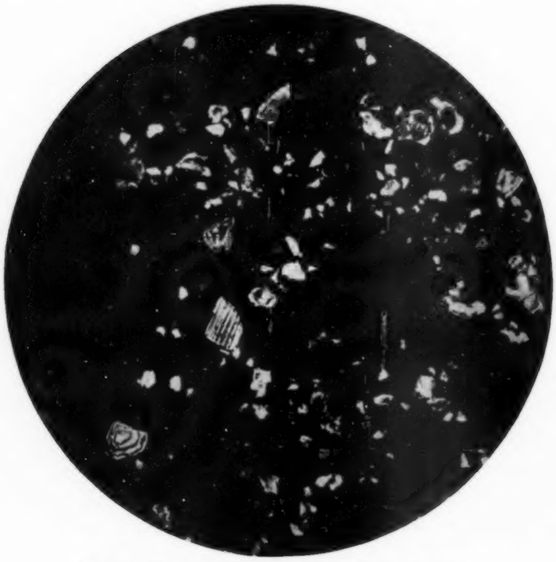

FIG. 2.—Same sample in polarized light (× 25)

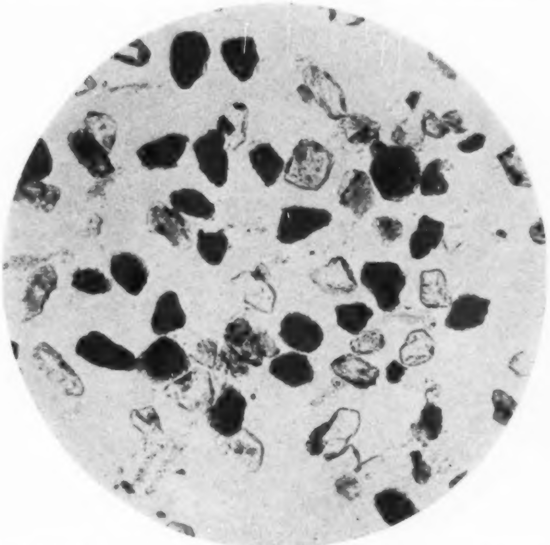

FIG. 3.—"Light" mineral crop from same sample (× 25), mostly quartz feldspar; the dark grains are decomposed feldspar.

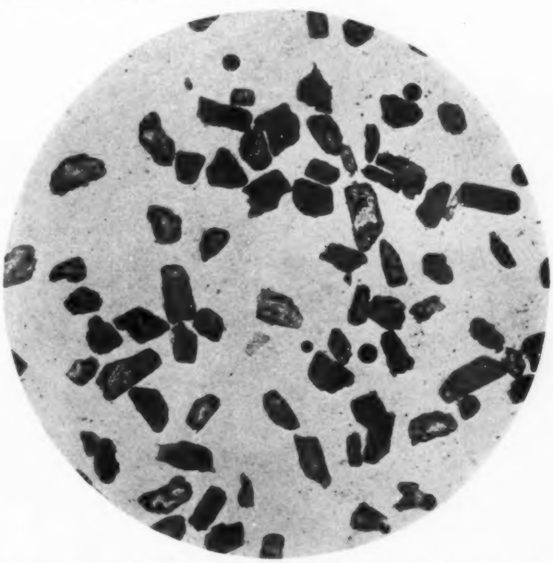

FIG. 4.—"Heavy" mineral crop from same sample (× 25), mostly amphiboles and hypersthene.

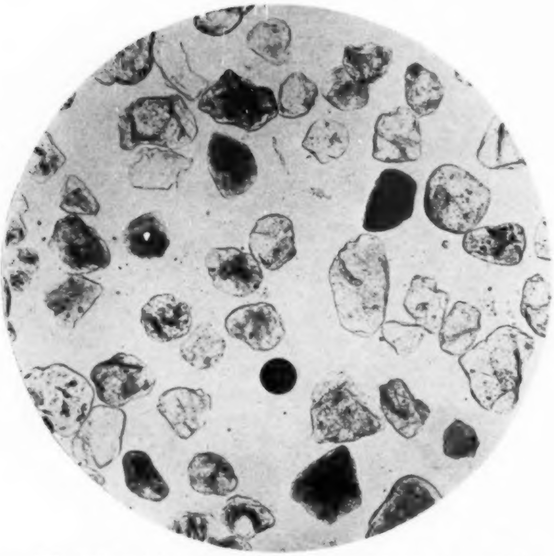

FIG. 5.—Washed sand (× 25). Note different character of material from that of Figure 1. Contains both rounded and angular quartz, plagioclase, decomposed feldspar, etc.

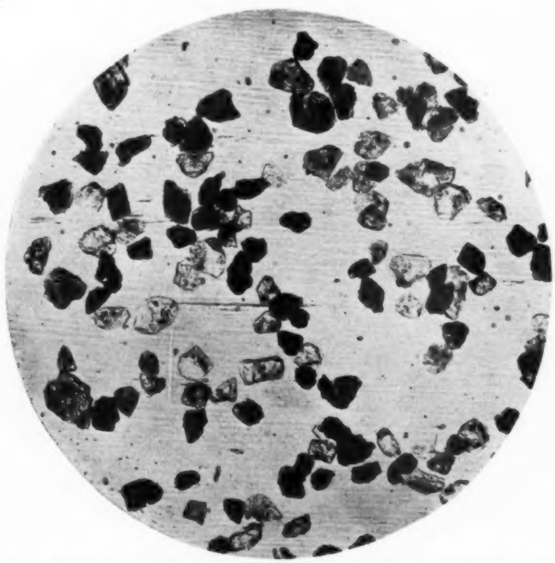

FIG. 6.—Poorly washed sand (× 25). Note ferruginous coatings on grains

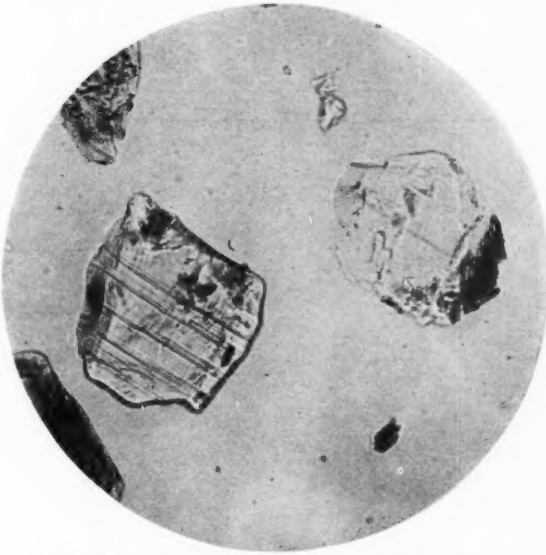

FIG. 7.—Quartz and plagioclase from the light crop (× 100)

FIG. 8.—Same field as Figure 7 in polarized light (× 100)

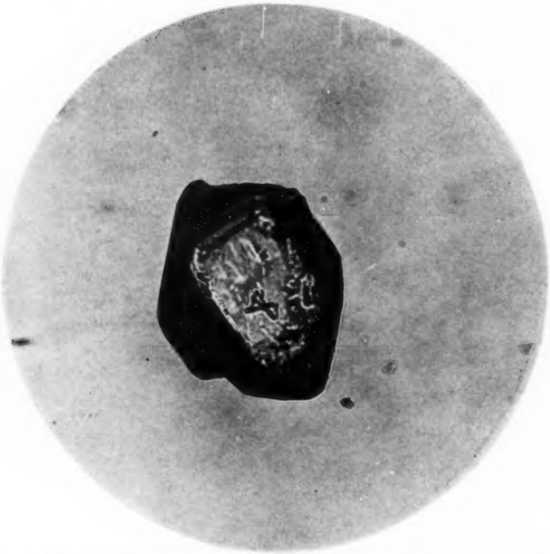

FIG. 9.—Monazite crystal from the weakly magnetic heavy crop (× 150).

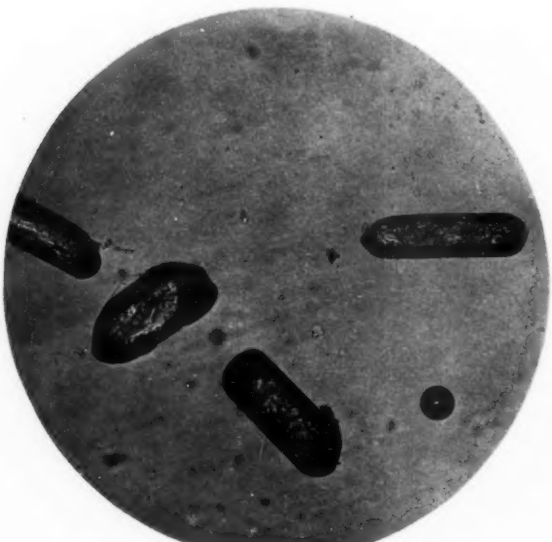

FIG. 10.—Zircon crystals from the non-magnetic heavy crop (× 85).

FIG. 11.—Water-rounded garnets from the moderately magnetic heavy crop (× 85).

FIG. 12.—Hypersthene fragments from the moderately magnetic heavy crop (× 85). The jagged terminations are characteristic of the pyroxenes.

THE HEAVY MINERALS

Certain minerals are present in nearly all sedimentary rocks, and the relative proportion of these common minerals may have very little correlative significance. Quartz and feldspar, for example, make up 95 per cent of most sandstones. Conceivably, the ratio of one's amount to the other's might be unusual and noteworthy, but more often the reverse would be true.

There is another group of minerals, however, representatives of which are seldom notable in a sediment, and more often rare, but which contribute to the identification of beds to a far greater degree than their abundance would seem to warrant. These are the so-called "heavy minerals," minerals of high specific gravity, with which property is usually combined great resistance to abrasion and chemical action. The durability of these minerals insures their preservation under most conditions of sedimentation, and they are found, therefore, in all sediments, whether fine or coarse textured. Their high specific gravity allows an easy separation from the main mass of the rock.

The heavy minerals most commonly found in California oil-field sediments are, in order of their relative abundance: (1) amphiboles; including hornblende, basaltic hornblende, actinolite and glaucophane; (2) pyroxenes; including hypersthene, augite, and diopside; (3) the opaque minerals of metallic luster, such as magnetite, ilmenite, chromite, pyrite, and others; (4) epidote; (5) the micas; (6) garnets; (7) zircon; (8) tourmaline; (9) apatite; (10) rutile; (11) monazite, (12) kyanite; (13) brookite; (14) andalusite; (15) topaz; (16) corundum; (17) staurolite.

PREPARATION OF SAMPLES

A 300-gram sample is digested in dilute hydrochloric acid for several hours or until all calcareous and ferruginous matter is dissolved. The heavy minerals will not be attacked to any perceptible degree by the acid. After decanting off the acid, the sample is panned to get rid of the very light minerals, some of which are mounted for microscopic examination. The residue is dried and placed in a large evaporating dish with a sufficient quantity of bromoform so that the quartz, feldspar, and other light minerals float on the surface and can be skimmed off, several washings

resulting in a heavy residue relatively free from all light minerals. This residue is washed with benzol, dried, and the magnetite, ilmenite, chromite, etc., removed with a bar magnet. The heavy crop may then be mounted in Canada balsam on an object slide, or it may be divided into several other crops of differing magnetic susceptibilities by means of an electro magnet and variable resistance. This last operation is not usually necessary.

THE STUDY OF MINERAL GRAINS

The microscopic study of mineral grains is made with a polarizing microscope, but the methods differ considerably from those of ordinary petrographic work on thin sections of rocks. In the study of thin sections much attention is paid to the determination of birefringence of the minerals. This is possible because all are cut to one thickness in the section, whereas, with mineral grains, all are different thicknesses and the determination of birefringence becomes difficult or impossible.

Offsetting this difficulty, however, is the greater ease with which refractive index may be determined in mineral grains. A grain may be isolated, immersed in a fluid of any desired refractivity, and turned or rotated to any desired orientation.[1] Optical character is also determined with greater ease in mineral grains than in thin sections because, in general, the thickness is greater and the interference figures better. For the same reason pleochroism is prominently displayed, and some mineral species may be recognized almost from this property alone. The relation of cleavage to optical orientation and the shapes of cleavage fragments are other important diagnostic points that are frequently used.

After one becomes familiar with most of the heavy minerals they may be recognized, under the microscope, almost on sight. It is rarely necessary to use more than two or three rapid tests on a grain in order to classify it.

A convenient method in the study of a mounting is to count 100 grains, using a mechanical stage, and list the names of the species encountered with the number of their occurrences. This will give a rough estimate of the percentage, by number, of each

[1] Larsen, "Microscopic Determination of the Non-opaque Minerals," *U.S. Geological Survey Bulletin 679.*

constituent. For example, note the counts from two samples of the Fernando of Ventura River:

	(1)	(2)
Glaucophane	26	0
Epidote	8	35
Titanite	20	13
Zircon	2	29
Garnet	1	17
Monazite	5	0
Tourmaline	1	0
Amphibole (green)	27	0
Turbid grains	10	6
	100	100

Each of these samples is typical of a certain zone in this formation; one is obviously a glaucophane and green amphibole zone and the other an epidote zone.

The counts of two samples from the region south of Coalinga illustrate the same point:

	(3)	(4)
Glaucophane	0	7
Epidote	5	3
Titanite	6	9
Zircon	25	1
Garnet	2	1
Monazite	0	0
Tourmaline	1	0
Amphibole	0	48
Rutile	3	0
Apatite	1	0
Augite	0	13
Turbid and opaque	57	18
	100	100

No. 3 is from the Tejon (Eocene) and contains no amphiboles nor pyroxenes; No. 4 is from the Monterey-Temblor and has these minerals in abundance.

Study of the heavy minerals constitutes a valuable aid in the correlation of oil-field formations, supplementing and verifying the evidence of the microscopic fossils, or filling the gap where fossils are not found.

Mineral grains are not destroyed by the drill; well samples are just as suitable for study as outcrop samples, and of course core-barrel samples offer the best material of all. Much significant information would be obtained by their systematic microscopic study.

September 20, 1923

THE OIL FIELDS OF CHINA[1]

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Geological Survey of China, Peking

INTRODUCTION

The oil fields of China are in the western and northwestern provinces of the country. In Sinkiang Province, oil territory is found along the northern side of the Tienshan Mountains, and from there it extends eastward into Kansu and Shensi provinces, along the northern side of the Tsinglingshan Mountains. It is also found in Szechwau Province, along the southern side of the Tsinglingshan Mountains. In general, these fields surround the northern and eastern sides of the plateau of Tibet. Although there are some outcrops of oil shales in Chili, Shansi, Honan, and Shantung provinces, no oil has yet been found.

Among the oil fields just mentioned, there are two most important fields, Shensi and Szechwau.

SHENSI FIELD

The oil of the Shensi field is found in Yenchang, Yenchwau, Yichwau, Anshih, Fusze, Kanchwau, Fuhsien, Chungpu, Yichum, Tungkuan, and Sinyi districts of the northern part of the province. The geological formations of this field are of pre-Cambrian to Mesozoic ages. The accompanying cross-section (Fig. 2) shows that the pre-Cambrian crystalline schists and granites occur at the eastern boundary of the provinces. The Cambro-Ordovician limestones and quartzites outcrop west of the pre-Cambrian, and the Carboniferous coal-bearing series, the Permo-Triassic red sandy shale, the Mesozoic, most probably the Jurassic, oil-bearing shales, sandstones, and coal, and the post-Jurassic cross-bedded sandstone and shale are found in this order toward the west. The oil-bearing formation in Shensi is a series of gray sandstones and

[1] Paper delivered at International Petroleum Exposition and Congress, Tulsa, Okla., Oct. 8–14, 1923. Manuscript submitted to the Association, November, 1923.

shales with a little coal in the upper part. The whole formation is about 6,300 feet thick. The oil of Yenchang district is found in the lower part of this formation, the oil of the Fusze and Kanchwau districts in the middle part, and the oil of the Chungpu, Yichum, and Tungkuan districts in the upper part. Oil springs are found in many places. The oil seeps from fissures in the shales and the sandstones. The oil formation extends southward into Sinyi and

Yenchang(延長)	Yichum(宜君)
Yenchwau (延川	Tungkuan(同官)
Yichwau(宜川)	Sinyi(栒邑)
Anshih(安塞)	Carboniferous coal bearing series,山西層
Fusze(膚施)	Permo-Triassic red sandy shale 汾河層
Kanchwau(甘泉)	Jurassic, oil bearing shales 陝西層
Fuhsien(鄜縣)	Kiating(嘉定)
Chungpu(中部	Tzuliuching(自流井)
Weiyuan(威遠)	Yunghsien(榮縣)
Niuhuachi (牛華溪)	Chukantan (竹根灘)
Paeshanching ([illegible]山井)	Paeshanching ([illegible]山井)
Lingwu(靈武)	Chengchun(鎮戎)
Yungchang(永昌)	Huating(華亭)
Toukwang(敦煌)	Zuechuan(酒泉)
Kuchu(庫車)	Yumen(玉門)
Dihua(迪化)	Wusu(烏蘇)
Taecheug(塔城)	Suilai(綏來)

AUTHOR'S TRANSLATION OF CHINESE CHARACTERS

FIG. 1

extends northward into Mongolia. The whole formation dips gently westward so that the oil wells of the eastern part are much shallower than those of the western part. This is shown by the wells of Yenchang district, 200 feet deep, and the wells of the western districts, 1,700 feet deep. The sandstone overlying the oil-bearing formation is about 3,000 feet thick and is cross-bedded in the lower part. Near the bottom of this sandstone there is a shaly limestone 100 feet thick. This also contains oil at some other places.

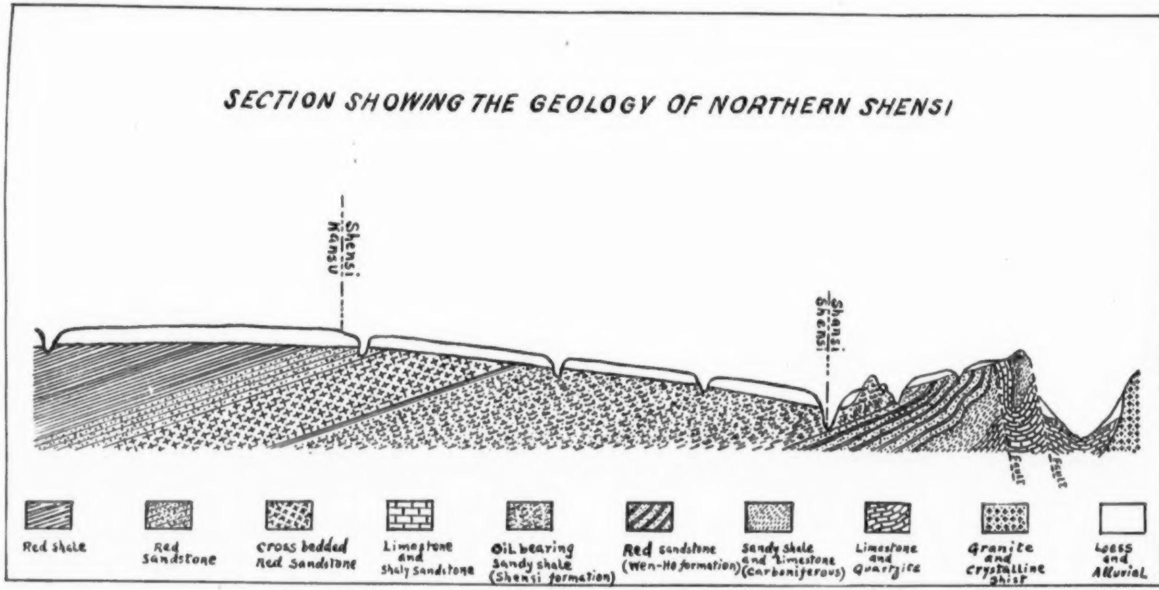
SECTION SHOWING THE GEOLOGY OF NORTHERN SHENSI
Shensi
Kansu
Shensi
Shensi
Fault
Fault
Red shale
Red Sandstone
Cross bedded Red Sandstone
Limestone and Shaly Sandstone
Oil bearing Sandy shale (Shensi formation)
Red sandstone (Wen-Ho formation)
Sandy shale and limestone (Carboniferous)
Limestone and Quartzite
Granite and crystalline Schist
Loess and Alluvial

FIG. 2

The result of prospecting wells which have been sunk in this field by the Chinese Bureau of Mines and the Standard Oil Company may be tabulated as follows:

TABLE I

TABLE SHOWING PROSPECT WELLS IN THE SHENSI FIELD, CHINA

Number of Wells	Location	Depth of the Wells from Surface in Feet	Depth of the Oil from Surface in Feet
1 (C.B.M.)	475 feet N.W. from the west city gate of Yenchang	340	210
2 (C.B.M.)	425 feet N.W. from No. 1	380	370
3 (C.B.M.)	350 feet N. from No. 1	600	160
4 (C.B.M.)	2,000 feet S.E. from the east city gate of Yenchang	400	....
Yenchang 1 (S.O.C.)	625 feet S.W. from No. 1	2,770	255 365
Yenchang 2 (S.O.C.)	7 miles N.E. from Yenchang	2,000	418
Yenan 1 (S.O.C.)	3.5 miles N.E. from Yenan	3,000	1,145 1,140 1,266
Chungpu 1 (S.O.C.)	3 miles S.W. from Tientouching of Chungpu	3,545	280–290 1,003 1,378 1,420 1,776
Chungpu 2 (S.O.C.)	5 miles S.W. from Tientouching	2,500	1,700
Chungpu 3 (S.O.C.)	13 miles N.W. from Tungkuan	2,800	....

An analysis of the crude oil produced from the wells of the Chinese Bureau of Mines is tabulated below.

	Per Cent
Light-distillates	1.5
Gasoline	2.5
Naphtha	8.5
Inferior naphtha	4.5
Kerosene	54.0
Lubricating oil	1.75
Paraffin	2.00
Petroleum coke	10.00
Loss	14.15

	Crude Oil	Refined Oil	Fuel Oil
Gravity	30 Be	41 Be	26 Be
Per cent	100	39.23	59.72

The proportion of the refined oil and the fuel oil varies from time to time. The production of crude oil from the Chinese Bureau of

Mines in 1917 was 750,000 catties, or approximately 2,582 barrels, in which more than one-third was refined oil.

SZECHWAU FIELD

The oil of Szechwau Province is found in the Kiating and Tzuliuching districts. Geologically, Szechwau has a basin structure. The early Paleozoic formations, mostly limestones, occur along the border of the province, forming the high mountains, and the Carboniferous, Permian, Mesozoic coal-bearing formations and the red sandstone occur successively toward the interior. The red sandstone covers a large part of the center of the basin. The oil, gas, and salt water are all taken from the lower part of the red sandstone formation. The cross-bedded sandstone of the upper part of the formation overlies the oil-bearing beds. In the main basin there are two parallel anticlinal folds. Kiating is at the western end of the northern anticline and from there the fold extends eastward through Yunghsien and Weiyuan. The dips of the strata are so gentle that the maximum angle of the northern limb of the anticline is about 8 degrees and that of the southern limb is 2 degrees. The oil wells are mostly dug along the northern limb, and these are dug for both oil and salt. The location, depth, and result of drilling accomplished to date are given in the following table.

TABLE II

TABLE SHOWING PROSPECT WELLS IN THE SZECHWAU FIELD, CHINA

Number of the Mining Localities	Location	Depth of the Wells from Surface in Feet	Depth of the Salt Beds from Surface in Feet	Depth of the Oil or the Gas from Surface in Feet
1	Niuhuachi	2,000–2,400	1,900	gas, 1,000
2	Chukantan	1,710	1,710	oil, 1,710
		1,660	1,660	gas, 1,660
		1,550	1,550	oil, 1,550
3	Between Chukantan and Faeshanching	250–700	250–700	oil, 250–700
		1,740	1,740	oil, 1,749
		1,650	1,650	oil, 1,650
4	Faeshanching	1,400–1,600	1,400–1,600	oil, 1,400–1,600

The southern anticline, which is in the vicinity of Tzuliuching, extends about 10 miles from east to west. Its two limbs dip north and south, respectively, about 10 degrees, and the anticline

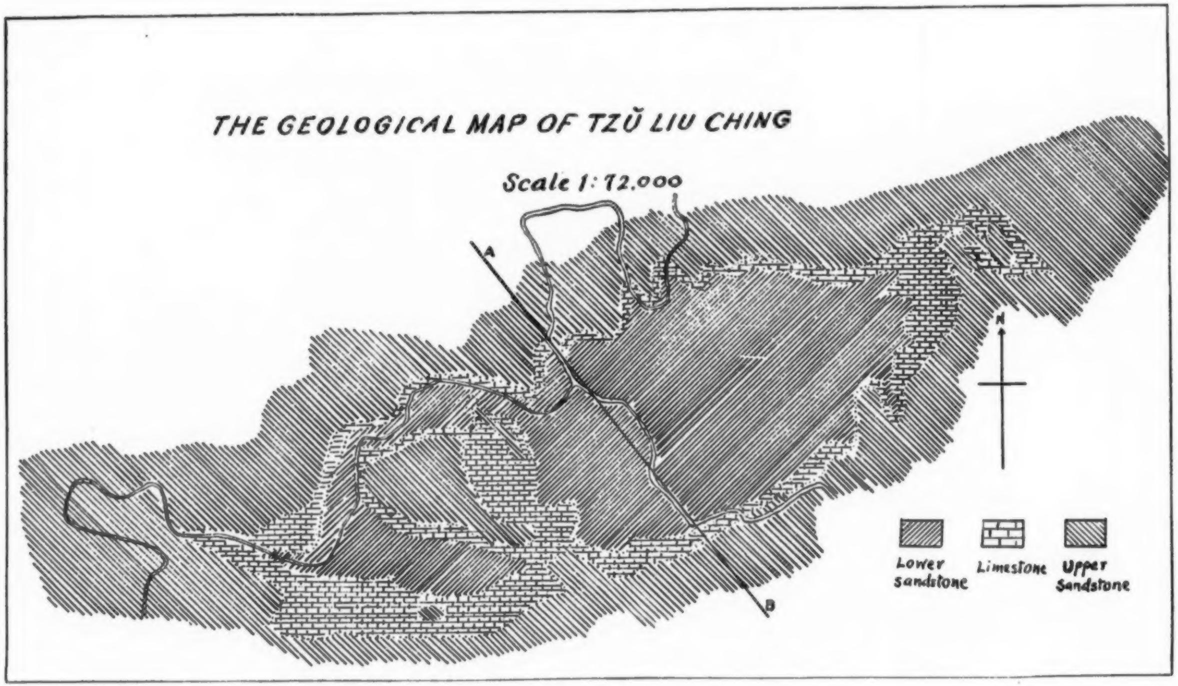
THE GEOLOGICAL MAP OF TZŬ LIU CHING
Scale 1: 72,000
A
B
N
Lower sandstone
Limestone
Upper Sandstone

FIG. 3

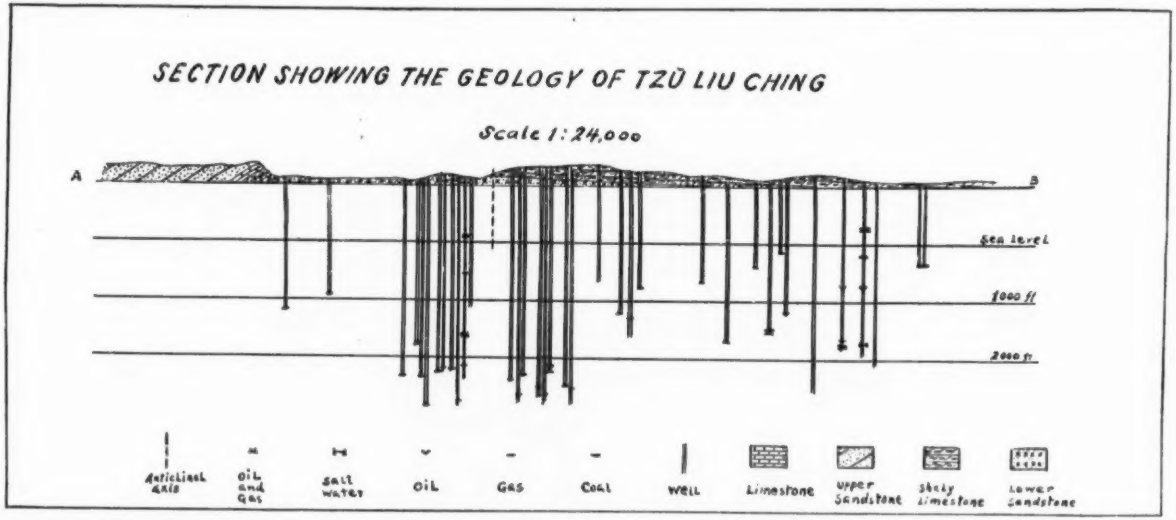
SECTION SHOWING THE GEOLOGY OF TZÜ LIU CHING
Scale 1:24,000
A
B
Sea level
1000 ft
2000 ft
Anticlinal axis
Oil and Gas
Salt water
Oil
Gas
Coal
Well
Limestone
Upper Sandstone
Shaly Limestone
Lower Sandstone

FIG. 4

is closed at both ends. The rocks outcropping in this region may be classified into three groups: (1) the uppermost a yellow to brownish fine-grained sandstone which shows also cross-bedding and is interbedded with red and greenish shale; (2) the next a grayish green and light yellow-colored limestone interbedded with shale, the total thickness of the limestone about 100 feet; and (3), the lowermost a sandstone and red shale about 600 to 700 feet thick. The rocks which have been found in the wells are coal-bearing shales and sandstones 1,500 to 2,000 feet thick, dolomitic limestone interbedded with shale and red shales. The salt water, oil, and natural gas are all found in the formations below the limestone. A generalized columnar section showing the details of the oil-bearing formation is presented in Figure 5, and a map (Fig. 3) and cross-section (Fig. 4) of the anticline.

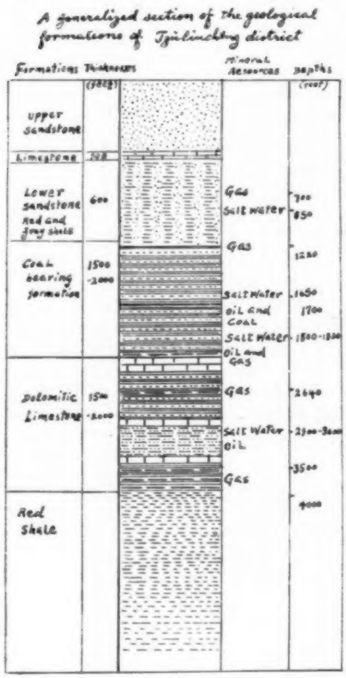

FIG. 5

More than a thousand wells have been drilled along the anticline, and about one-fifth of these wells are oil-productive. The deepest wells of this region are over 4,000 feet. The production of oil varies from time to time. During the year 1918, the total production was 250 catties daily, equivalent to approximately 300 barrels a year. The oil produced in this region is used as fuel for the purpose of evaporation of the salt water, and for such it is used in the crude state.

OTHER OIL PROSPECTS

Besides these two oil fields, it has been reported that oil is found in Lingwu, Chengchun, Kuyuan, and Huating districts of

the eastern part of Kausu Province, and in Yungchang, Zuechuan, Yumen, and Toukwang districts of the western part of Kausu Province. It has been also reported that oil is found and collected from sixty-five springs scattered in Wusu, Kuchu, Suilai, Dihua, and Taecheug districts of Sinkiang Province. Because of the lack of detailed geological study and prospecting work in these provinces, detailed data are not available.

CONCLUSION

The oil fields of China cover a very large area, and probably one-fourth of the area of the whole country is promising for the discovery of oil. Two fields are at present more or less developed, the Shensi and the Szechwau, but there is no profitable commercial production of oil in these fields. The geological formations of the northwestern provinces and the interior of Mongolia are almost similar to the Shensi and Szechwau fields. Important oil fields in other provinces will almost certainly be found if further prospecting work is carried on.

SANTA FE SPRINGS FIELD, CALIFORNIA[1]

R. R. TEMPLETON AND C. R. McCOLLOM
Los Angeles, California

INTRODUCTION

About ten years ago a great flood of oil from the famous Cushing Pool of Oklahoma drove the price of oil down to as low as 17 cents per barrel and forced the abandonment of thousands of small wells throughout the country, necessitated the construction of vast amounts of storage, and resulted in a great waste of oil and gas. Today a similar overproduction in southern California, largely on account of the Santa Fe Springs field, is seriously affecting the oil industry. The Cushing field reached its peak production in April, 1915, when it threw about eight and one-half million barrels of oil on the market. During the past two months Santa Fe Springs has produced more than ten million barrels of oil per month, and the production is now standing at about that figure. As a result, the industry in the Mid-continent is almost paralyzed, the transportation and refining facilities of the Atlantic coast are taxed to the limit, and the price of gasoline has been universally forced down to a point where only few refiners are able to make a profit.

This production, which represents about one-sixth of the production of the United States, is the more remarkable when it is considered that this tremendous flood of oil is coming from a field comprising only some 1500 acres of proved oil land, and that the oil is coming from the heretofore unheard of depth of nearly a mile.

LOCATION OF STRUCTURE

The Santa Fe Springs field is named after the little town of Santa Fe Springs, located about twelve miles southeast of the

[1]Read before the Los Angeles meeting of the Association, September, 1923. Manuscript received by the Editor, November, 1923.

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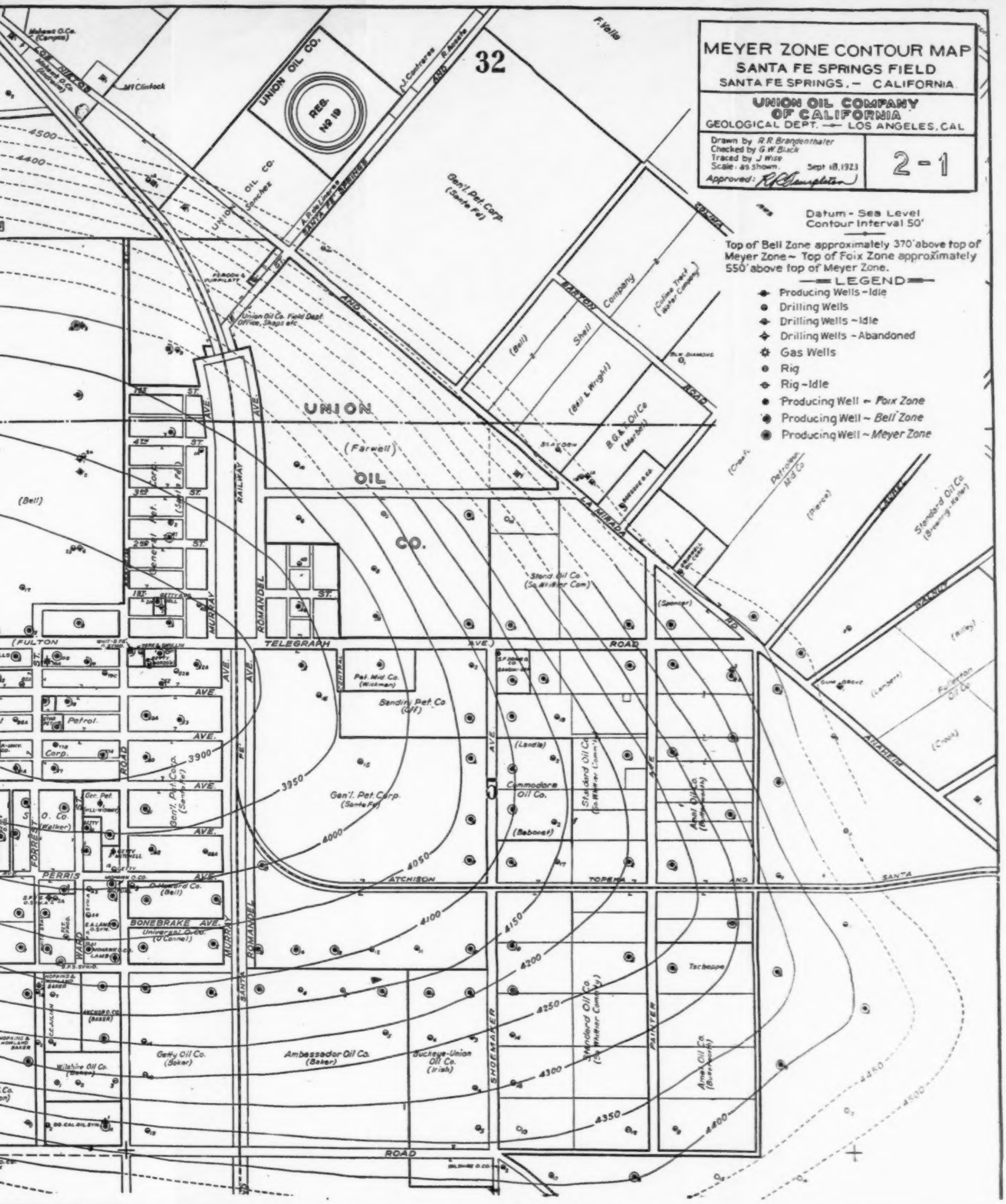
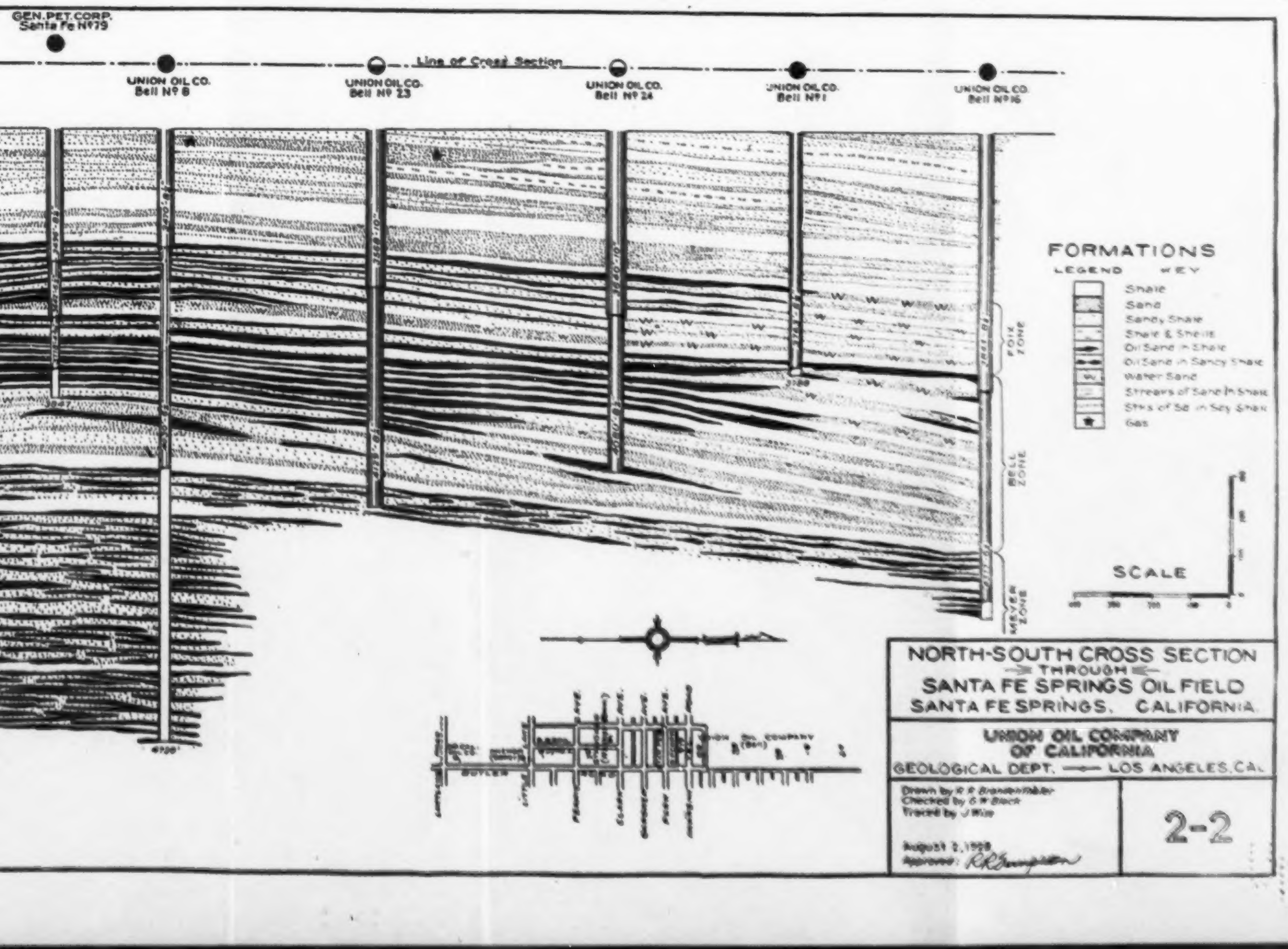
31
Stand. Oil Co. (Pac. Clay Prod.)
UNION
OIL
CO.
Standard Oil Company
W. L. Houghton
A. O. Houghton
T. 2 S.
T. 3 S.
J. J. Orr
TELEGRAPH
ROAD
FULTON WELLS
Stand. O. Co. (Santa Gertrudes)
Amal. O. Co. (Dallugge)
Stand. O. Co. (Hoyer)
Shell Co. (G. Hall)
Amalgamated Oil Co.
Oscar Howard Co. (Hathaway)
Gen. Pet. Corp.
Shell Co. (Slugher)
Pet. Mid. Co. (Mattern-3)
ANAHEIM
PARK
GARDNER
CLARK
LAKE
LAKELAND
6
H. B. Miller
S. A. Crawford
N. A. Fischer
A. Loveall
C. E. Archer
E. A. Loveall
K. B. Norswing
School
Norwalk Gas Plant
M. E. Gill
Stand. O. Co. (Johnson)
Pet. Mid. Co. (Patterson)
Stand. O. Co. (Koontz)
4350
4300
4250
4200
4150
4100
4050
4000
3950
3900
4500
SOUTHERN CAL. OIL CO.
ANCHOR OIL CO. Baker No. 1
S. F. SPGS. SYNDA. No. 1
STANDARD OIL CO. Walker Comm. No. 2
STANDARD OIL CO. Walker Comm. No. 1
STAR PET. CO. No. 2
3000' below Sea Level


MEYER ZONE CONTOUR MAP
SANTA FE SPRINGS FIELD
SANTA FE SPRINGS, - CALIFORNIA.
UNION OIL COMPANY OF CALIFORNIA
GEOLOGICAL DEPT. — LOS ANGELES, CAL.
Drawn by R.R. Brandenthaler
Checked by G.W. Black
Traced by J. Wise
Scale - as shown
Sept 18, 1923
Approved: R.R. Templeton
2-1
Datum - Sea Level
Contour Interval 50'
Top of Bell Zone approximately 370' above top of Meyer Zone ~ Top of Foix Zone approximately 550' above top of Meyer Zone.
LEGEND
Producing Wells - Idle
Drilling Wells
Drilling Wells - Idle
Drilling Wells - Abandoned
Gas Wells
Rig
Rig - Idle
Producing Well ~ Foix Zone
Producing Well ~ Bell Zone
Producing Well ~ Meyer Zone
32
5
UNION OIL CO.
UNION OIL CO.
Gen'l. Pet. Corp. (Santa Fe)
Shell Company
Standard Oil Co.
Commodore Oil Co.
Sanders Pet. Co.
Ambassador Oil Co.
Getty Oil Co.
Buckeye-Union Oil Co.
Amal. Oil Co.
Wilshire Oil Co.
Fullerton Oil Co.
TELEGRAPH
ATCHISON
TOPEKA
SANTA
BONEBRAKE AVE.
PERRIS
FULTON
LA MIRADA
ANAHEIM
RAILWAY AVE.
ROMANDEL
MURRAY
SHOEMAKER
PAINTER
ROAD
3900
3950
4000
4050
4100
4150
4200
4250
4300
4350
4400
4450
4500


GEN. PET. CORP. Santa Fe Nº 79
Line of Cross Section
UNION OIL CO. Bell Nº 8
UNION OIL CO. Bell Nº 23
UNION OIL CO. Bell Nº 24
UNION OIL CO. Bell Nº 1
UNION OIL CO. Bell Nº 16
FOIX ZONE
BELL ZONE
MEYER ZONE
FORMATIONS
LEGEND KEY
Shale
Sand
Sandy Shale
Shale & Shells
Oil Sand in Shale
Oil Sand in Sandy Shale
Water Sand
Streaks of Sand in Shale
Stks of Sd. in Sdy Shale
Gas
SCALE
NORTH-SOUTH CROSS SECTION
THROUGH
SANTA FE SPRINGS OIL FIELD
SANTA FE SPRINGS, CALIFORNIA.
UNION OIL COMPANY OF CALIFORNIA
GEOLOGICAL DEPT. — LOS ANGELES, CAL.
Drawn by R.R. Brandenthaler
Checked by G.W. Black
Traced by J. Wise
August 2, 1923
Approved: R.R. Templeton
2-2

center of Los Angeles. The townsite of Santa Fe Springs, inside the proved limits of the field, comprises about 350 acres; it occupies approximately one-half of the top of the structure and is cut up in about 100 leases, all of which called for immediate drilling. This is responsible for the mad development which forced the large companies to follow the lead of the promotion companies and resulted in throwing on the market the present enormous production.

The structure of the field is a closed anticline whose axis trends northwest and southeast. No surface dips are exposed, but the possibilities of oil accumulation were suggested by the slightly elevated country and the presence of gas in water wells.

HISTORY OF EARLY DEVELOPMENT

In October, 1907, the Union Oil Company of California started a wild cat well known as Meyer No. 1, situated at the extreme southeast end of the field and outside of any present known productive area. It is probably fortunate that this well was abandoned at a depth of 1,445 feet on account of water sands, gas, and gravel which put the whole in such condition that it was impossible to continue. A year later a second well, Meyer No. 2, was started with an imported Texas rotary outfit and crew. At a depth of only 350 feet a string of tools had been lost and so much difficulty had been experienced that the hole was abandoned. This well was also located outside the limits of production.

About eight years elapsed before a third attempt was made at Meyer No. 3 well, which was spudded February 12, 1917, with a Union Oil Company rotary outfit and crew. For two years and seven months a hard fight was made, during which time the rotary was replaced twice by cable tools and many difficult fishing jobs overcome, but finally on October 3, 1919, the well came in flowing at a rate of about 3,000 barrels of oil per day at a total depth of 4,595 feet. After a few hours water broke in and killed the production. Water was shut off upon recementing, but the production came back at a rate of only about 150 barrels per day. This small production failed to create much excitement, but it served to prove the existence of an oil field, and has the distinction of being the discovery well of this now famous field.

Again the Union Oil Company sought to prove the correctness of its convictions and on September 7, 1919, spudded Bell No. 1 well located one and one half miles northwest of Meyer No. 3. After another hard campaign of over two years the well was brought in at a depth of 3,788 feet, flowing 2,000 barrels per day of 31 gravity oil. Coming unexpectedly, this completion brought a stampede of promotion men and representatives of large companies offering almost unheard of royalties, bonuses, and drilling agreements. The town site with its many ownerships offered the promoters just the opportunity they wanted, while the larger tracts were eagerly snapped up by the major companies. During the remainder of 1921, 13 drilling notices were filed with the department of petroleum and gas of the California State Mining Bureau, 255 in 1922, and 179 for the first five months of 1923.

In December 1922 there were 70 producing wells and 166 drilling wells, and on September 13, 1923, there were 211 producing wells and 191 wells drilling. The peak of drilling wells was reached June 7, 1923, when 249 wells were reported. Present developments are being carried on all over the field, but most attention is being directed toward the northwestern part, where it is agreed the future increase in production must be obtained, if at all.

FORMATIONS PENETRATED IN DRILLING

The surface formations in the Santa Fe Springs field are sticky clays and loose unconsolidated sandy shales, sands, and gravels. Underlying these there is a thick shale bed which serves as a fair marker for correlations on top of the structure, and also as a cap for a high pressure gas zone which has blown out and completely wrecked four wells and partly wrecked five others. Two gas wells have been successfully completed in this zone and together are now producing about ten million cubic feet of gas daily. This gas zone is encountered at depths ranging from 2,000 to 2,100 feet and consists of sandy shales, sands and shales with streaks of sand. It is probable that the gas zone is about 1,500 feet thick and continues close to the top of the first oil zone, although the blowouts have occurred in the top portion of it.

The Foix oil zone, Bell oil zone, and Meyer oil zone, in the order named underlie the gas zone. These zones are separated by shale

bodies and are distinguished chiefly by the differences in depth and by the oil gravities and properties. The term "zone" is used almost universally in designating these productive formations because they are not pure sands but sandy shales and interbedded sands and shales. Many of the shales do not show an oil cut when treated with chloroform, but nearly all sandy shales and sands will cut; however, they all go to make up a continuous zone. In the Bell and Meyer zones a number of hard sands are encountered and hard-rock bits are used.

Unlike most fields in the Mid-continent, the areal extent of the productive limits of the field increases with the deeper zones. That is, the proved productive area of the Foix zone is limited to about 28 acres, that of the Bell zone to about 600 acres, and that of the Meyer zone to about, 1,500 acres. No oil formations as yet have been penetrated below the Meyer zone, but it is possible that they may be uncovered with deeper drilling.

Foix Oil Zone.—The first oil from the Foix zone was obtained by the Petroleum Midway Company in its Foix No. 1 well at a depth of 3,500 feet. It was obvious that this sand was not the same as that found in Union Oil Company's well, Bell No. 1, on account of its being much higher stratigraphically and on account of the low gravity of the oil and the corresponding low gasoline content.

Because of the low gasoline content of the oil this zone was developed by only five wells—all in the town-site area—which wells in October, 1922, were making a total production of about 6,000 barrels daily. Four of these wells have since been deepened, while the remaining one, Union Oil Company's well, Alexander No. 2, is still producing daily about 950 barrels of 25 gravity oil with a cut of 1 per cent sand and pressures of 150 pounds per square inch on the tubing and 420 pounds on the casing.

A water is found outside of the productive limits of the Foix zone and probably completely underlies the producing horizons of the zone, although this has not been definitely proved. Union Oil Company's well Alexander No. 2 has penetrated the zone only about 25 feet.

The Foix zone has an average thickness of about 180 to 185 feet and consists of sandy shales and interbedded sands, shales,

and shells. On top of the structure the sands and sandy shales contain oil and gas, but farther out these formations carry water. The bottom 20 to 40 feet of the Foix zone consists of a sticky brown shale which directly overlies and caps the Bell zone.

Bell Oil Zone.—The top of the Bell zone, within the limits of its production, is found at depths ranging from about 3,650 to 3,850 feet. It has an average thickness of about 370 feet of which approximately the upper 200 feet are oil sands, sandy shales bearing oil, and interbedded sticky brown shales, all of which compose the productive portion of the zone. Below these are found water sands, sandy shales, and sticky brown shales. The base of the Bell zone consists of about 30 to 50 feet of sticky brown shale, sometimes logged sandy shale, which caps the Meyer zone.

Until the latter part of 1922, when the Standard Oil Company completed its well, South Whittier Community No. 4, in the Meyer zone with an initial production of about 4,500 barrels of 35 gravity oil, all efforts were directed toward developing the Bell zone production. In fact, little attention was diverted from the Bell zone until the Elliott Petroleum Corporation on February 15, 1923, brought in from the Meyer zone its Clark No. 1 in the extreme west end of the field with a flow of better than 6,000 barrels of 35.2 gravity oil. At this time the total daily production of the field was reported at 111,078 barrels from 74 producing wells, of which 5 were producing from the Foix zone, 49 from the Bell zone, and 19 from the Meyer zone.

On September 6, 1923, there were 32 wells producing from the Bell zone, making a total daily production for the zone of 16,032 barrels, or an average daily production per well of 486 barrels.

Edge water has encroached on the Bell zone with the decline of pressure so that now many of the wells are reduced to pumpers, and it is absurd to consider the zone as a factor which may seriously contribute to overproduction in the future.

Meyer Oil Zone.—The Meyer zone, although the first zone discovered, was the last to be considered seriously. After the Elliott Petroleum Corporation's well Clark No. 1 was brought in, all efforts turned to the Meyer zone, where some large wells were obtained and the production of the field began "skyrocketing."

Like the Foix and Bell zones above, the Meyer zone consists of brown shale and sandy brown shale with streaks of oil sand interbedded. Most of the shales show no oil cut when treated with chloroform.

The greatest penetration into the Meyer zone recorded is 860 feet in Star Petroleum Company's well No. 2, which is located close to the top of the structure. This well was still in oil formation at the bottom of the hole and made an initial production of 12,000 barrels daily on April 16, 1923. Five months later it had declined to 1,520 barrels daily, but was making clean oil.

The productive limits of this zone are now well defined in all sections of the field except a small portion in the northwest end, but it is probable that its areal extent will never exceed much more than 1,500 acres.

There appear to be three distinct oil horizons in the Meyer zone. The upper horizon is approximately 100 feet thick composed chiefly of sandy shale and streaks of sand carrying oil for about 60 feet and 40 feet of sticky brown shale, sometimes logged sandy brown shale, which apparently contains no oil. Wells completed in this portion of the Meyer zone, on top of the structure, have come in with an average initial production of about 4,000 barrels and have stood up well. The middle horizon, about 400 feet thick, is composed chiefly of sandy shales with interbedded sands and shales, with a body of brown shale at the bottom. Wells completed in this horizon, on top of the structure, have come in with an average initial production of about 4,500 barrels. This portion of the Meyer zone has been a big producer of oil and there are more wells finished in it than in any other. The lower horizon on top of the structure is approximately 375 feet thick and also consists of sandy shales carrying oil, shales, and interbedded oil sands. Most of the large wells of the field have been completed in these strata, the average initial production of those located well up on structure being better than 6,000 barrels daily.

On account of edge water conditions in the Meyer zone it is probable that the productive areal extent of the lower horizon does not exceed two-thirds of that of the productive limits of the upper and middle horizons. The only known water in the Meyer zone

is an edge water on the entire zone. There are no intermediate waters between the upper and middle horizons and middle and lower horizons so far as is known. In the extreme southeast end of the field there is some evidence that a finger of edge water comes in along the top of the Meyer zone and overlies productive oil formations; however, this has not been definitely proved.

On September 13, 1923, there were 179 wells producing from the Meyer zone and 191 drilling to it.

DETERMINATION OF UNDERGROUND STRUCTURE

The underground conditions of the Santa Fe Springs field have been determined mainly by contour maps, cross-sections, and peg models, and great assistance to these determinations has been afforded by many core barrel samples.

To date it is notable that this field has been comparatively free from any serious water troubles. This condition is undoubtedly due to the high efficiency of underground determinations and cementing operations. A large measure of this success is due to the state mining bureau which has held the situation well in hand.

Before attention was directed toward the development of the Meyer zone the large majority of shut-off determinations above the Foix and Bell zones were made from correlations without the assistance of many core barrel samples, and these determinations proved to be correct in most cases. With the development of the Meyer zone the core barrel came into high favor. Many companies set aside the correlations of their geological departments and resorted to coring to determine the top of the Meyer zone, with the result that a high percentage of the casing strings have either been set above the top of the zone, in which cases an extra string was often wasted, or into the zone, which has resulted in shutting off some of the top production and failure to give the same degree of assurance of a shut-off as a string cemented at the top of the zone. This is to be expected when it is realized that cores are generally taken every 10 to 15 feet and often 30 to 40 feet is made before the core barrel is run. The majority of cores obtained range in length from 2 inches to 24 inches, although 2 to 6 feet of hole is made to

get these cores, so it often happens that the oil sands are drilled through and the cores are taken in shale which shows no cut, or vice versa. In either event the shut-off point determination is wrong. This is not meant to underrate the value of coring, but merely to bring out its present inadequacy, and the failure of many companies to apply properly the information afforded by cores as now taken.

DRILLING POLICY AND PRACTICE

Drilling in this field has been done exclusively by rotary. The average drilling time with corresponding depths is about as follows:

Depth in Feet	Days	Average Daily Footage
0–1000	15	67
0–2000	33	61
0–3000	65	46
0–4000	145	28
0–4750	200	24

A large conductor string of casing is usually set at about the top of the gas zone and cemented to shut off surface waters from entering that zone, and furnish an anchor to tie to in case of threatened blowouts. The second string used is a water string. Within the productive limits of the Foix zone this string must be cemented on top of it. Outside of the productive limits of the Foix zone and inside the productive limits of the Bell zone this string must be cemented at the top of one or the other zones. If outside the productive limits of both zones the second string may be set at the top of the Meyer zone. Inside the productive limits of the Bell zone a third string is cemented at the top of the Meyer zone.

In all cases where any upper zones are productive the formations behind casings must be thoroughly mudded until the loss of mud with free and open circulation does not exceed one to two barrels per hour. This is done to insure the cement filling the annular space between the casing and walls of the hole where intended, and also to confine the contents to their original strata.

Where a conductor string is set at the top of the gas zone the formation behind the first water string must be mudded under pressure by introducing mud between casings, within six hours after cementing, and held at 250 pounds until the loss is not more than one barrel per hour. This affords further protection against blowouts and passage of oil, gas, and water from one stratum to another.

In a few cases, combination oil and water strings have been used where mechanical difficulties have made it impossible to carry out the usual program. A combination string is one in which the bottom portion is perforated to allow the passage of oil and gas into it. This serves the purpose of an oil string, above which large perforations are made, through which cement is forced to effect the water shut off. It is unanimously agreed that the use of combination strings is bad practice and is justified only as a last resort in a territory where the consequences probably will not be serious.

The fourth string used is an oil string, usually of $6\frac{1}{4}$-inch or $4\frac{1}{2}$-inch casings, set on bottom with perforations extending up from bottom to the top of the productive formations. Above this the casing is blank. The perforated portion of the oil string is made up of casing which may be machine perforated, torch slotted, or screen. The usual screen used is 60 to 100 mesh, with the average 80 mesh.

The only wells in the field that are not producing through perforated casing set on bottom are a few in which the casing stuck above the bottom. This perforated casing is necessary on account of sand troubles.

There is no well in the field producing from more than one zone as determined by oil gravities and content, although a few wells have the perforations extending up a short space above the main producing zone.

The average cost to drill and complete a well in the Santa Fe Springs field in the different zones is about as follows: Foix zone, $65,000; Bell zone, $85,000; Meyer zone, $125,000.

There were 211 producing wells in the Santa Fe Springs field on September 13, 1923, of which 190 were flowing and 21 pumping. With but three or four exceptions all wells flowed upon completion.

PRODUCTION

The range and average of initial productions from the different zones is as follows:

Zone	Range in Barrels		Average
	From	To	Barrels
Foix..........	602	2,500	1,535
Bell...........	110	3,900	1,525
Meyer.........	57	12,000	4,125

In the Meyer zone, particularly, there were marked differences in initial productions of wells completed at about the same time, in the same general locality, and at approximately the same depths. These differences can be accounted for to a large degree by the mechanical condition of the well and reflect the relative efficiency of the operating companies.

Up to the end of June, 1923, there had been produced a total of 42,215,534 barrels of oil from the Santa Fe Springs as follows:

Year	Production (bbls.)
1921......................	218,144
1922......................	10,834,502
First half 1923.............	31,162,888

Since July 1, 1923, there has been produced at least 25,000,000 barrels, so it is safe to say that the total recovery to September is about 67,000,000 barrels. The per acre recovery for the field then is about 45,000 barrels. It is estimated that this amount represents approximately 60 per cent of the ultimate recovery of the field, or the total per acre yield of the field will be about 75,000 barrels. It is estimated that the remaining 40 per cent will be recovered within the next two or three years.

DECLINE OF MEYER ZONE

The decline of the Meyer zone has been rapid, although the first impression gained from looking over the weekly total production figures is that it is well sustained. This impression is accounted for by the large number of wells that have been completed during the past few months. The decline of the average well in the Meyer zone, with an initial production of 7,900 barrels per day, is at the

rate of 8 per cent per day during the first month and .67 per cent per day during the following four months.

Contrary to the general opinion, the decline in the town lot area has been but little greater than the area outside of this district although the former has been drilled much more intensively. The following figures were taken from decline curves on the two areas:

Months	Production in Town Lot Area (bbls. per day)	Production outside Town Lot Area (bbls. per day)
1	9,969	7,907
2	7,500	6,000
3	5,500	4,800
4	4,200	3,775
5	3,200	3,000
6	2,400	2,400

Following are production and development statistics for Santa Fe Springs field since the end of June, 1923.

Date	Total Daily Field Production	No. Producing Wells	Aver. Daily Production per Well	No. Drilling Wells	No. Rigs	Production by Zones: Foix		Bell		Meyer	
						No. Wells	Prod.	No. Wells	Prod.	No. Wells	Prod.
1923											
July 5	317,484	147	2,160	215	38	1	793	36	16,358	110	300,333
July 12	337,835	153	2,208	224	54	1	792	36	17,678	116	319,365
July 19	322,890	160	2,018	200	48	1	700	32	13,503	127	308,597
July 26	326,978	160	2,044	210	46	1	902	31	14,499	128	311,577
Aug. 2	332,644	167	1,992	207	41	1	1,164	30	13,751	136	317,729
Aug. 9	339,222	170	1,995	204	44	1	1,102	28	13,559	141	324,561
Aug. 16	333,974	180	1,855	198	37	1	1,050	30	14,321	149	318,603
Aug. 23	341,561	188	1,817	198	41	1	1,001	28	13,673	150	326,888
Aug. 30	338,187	201	1,683	191	40	1	956	32	14,607	168	322,626
Sept. 6	346,705	203	1,708	186	30	1	954	32	15,078	170	330,673
Sept. 13	328,294	211	1,556	191	38	1	809	31	14,739	179	312,736

OIL GRAVITIES AND ANALYSES

The gravity of the Foix zone oil in the tank ranges from 24.6 to 27.8 Bé, the average being 26.5 Bé. This oil contains 6.7 per cent gasoline, 9.6 per cent engine distillate, and 0.9 per cent kerosene for an average. The Bell zone oil gravities fall within the limits of 25.5 and 32.3 Bé, the average being 30.2 Bé. The average content of this oil is 18.2 per cent gasoline, 7.6 per cent engine distillate, and 7.1 per cent kerosene. The Meyer zone oil ranges in gravity between 33.8 and 35.9 Bé with an average of 34.7 Bé. It contains an average of 35.6 per cent gasoline, no engine distillate, and 10.7 per cent kerosene.

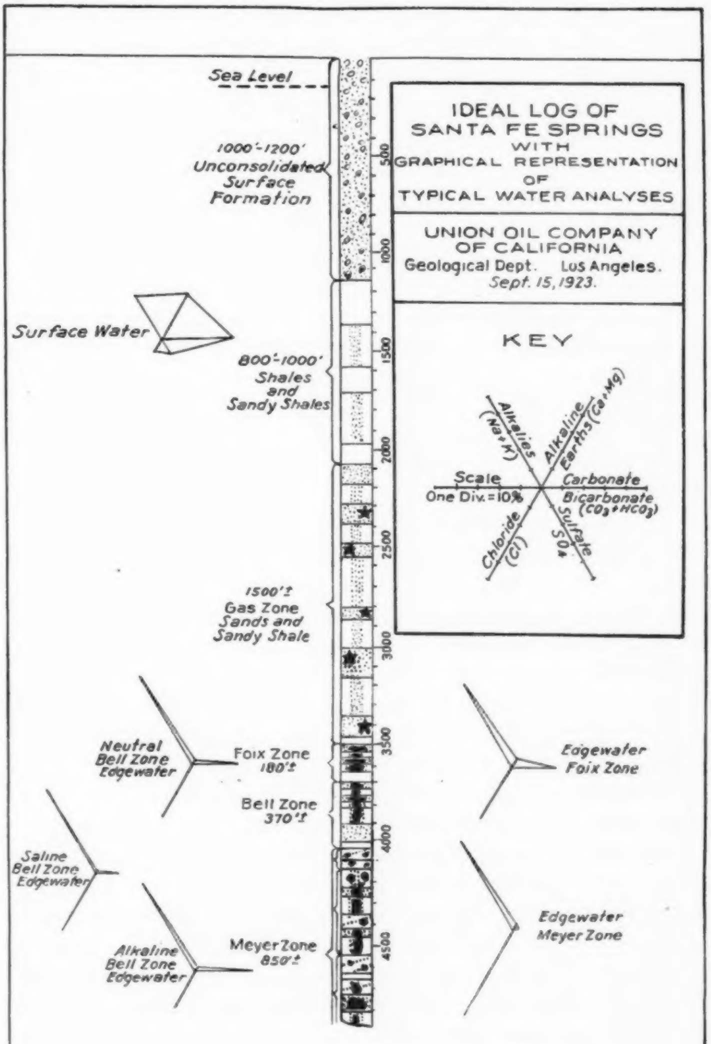

IDEAL LOG OF
SANTA FE SPRINGS
WITH
GRAPHICAL REPRESENTATION
OF
TYPICAL WATER ANALYSES
UNION OIL COMPANY
OF CALIFORNIA
Geological Dept. Los Angeles.
Sept. 15, 1923.
KEY
Alkalies (Na+K)
Alkaline Earths (Ca+Mg)
Scale
One Div.=10%
Carbonate
Bicarbonate (CO_3+HCO_3)
Chloride (Cl)
Sulfate SO_4
Sea Level
1000'-1200' Unconsolidated Surface Formation
Surface Water
800'-1000' Shales and Sandy Shales
1500'± Gas Zone Sands and Sandy Shale
Neutral Bell Zone Edgewater
Foix Zone 180'±
Bell Zone 370'±
Edgewater Foix Zone
Saline Bell Zone Edgewater
Alkaline Bell Zone Edgewater
Meyer Zone 850'±
Edgewater Meyer Zone
500
1000
1500
2000
2500
3000
3500
4000
4500

FIG. 1

WATER PROBLEMS

Water troubles have not as yet become serious in the Santa Fe Springs field although edge water has defined the limits of the field in all portions except the northwestern end, and there are now twenty-odd Meyer zone producing wells showing water. As far as the future development and operation of the field is concerned, it is felt that the water situation can be adequately taken care of. As the Meyer zone water is quite distinctive from upper waters, the proper remedial work can quickly be determined from a water titration.

Surface Water.—The surface waters are typical alkaline waters with a total solid content of from 500 to 1,000 parts per million. A fair average sample has the following analysis:

Total Solids	691.5
Na	138.7
Ca and Mg	118.1
SO_4	106.1
Cl	65.0
HCO_3 and CO_3	263.6

Oil Zone Waters.—The waters of the oil zone are altered connate waters, which may or may not be mixed with meteoric waters depending upon the horizon in which they are found. These waters are typically low in SO_4 content and the salt varies from 3,000 to 12,000 parts per million.

The waters of the Foix and Bell zones are mixtures of altered connate and meteoric waters, while that of the Meyer zone is an altered connate water with very little or no meteoric water.

Foix zone water is best distinguished from the Bell zone water by its higher content of alkaline earths—calcium and magnesium. The Foix water has an average alkaline earth content of 3.5 to 4.0 per cent whereas the Bell zone water averages from 1.5 to 2.0 per cent. This does not always hold, however, and at times it is necessary to study some of the minor characteristics to make a separation. Foix water is easily distinguished from Meyer water by the great difference in concentration, primary alkalinity, alkaline earths, and carbonate chloride ratio.

The Bell zone water shows a higher average concentration of dissolved salts than the Foix water, but a smaller content than Meyer water. This distinction is not entirely definite throughout

the field, however, and other qualities must be considered to effect a good separation. Study of analyses of the Bell zone waters indicates that the water is probably coming from one horizon but is variable in character. Samples taken from the top and north side of the structure show an alkaline rather than a saline character. Other samples obtained from the southwestern and western flanks and outside of the productive area are true saline waters, some of which are difficult to distinguish from Meyer zone water. Between these two extremes the waters grade into neutral waters. These variations are probably caused by differences in alteration accompanied by a small amount of intermingling and migration of the water, and also by pollution. These waters can be conveniently referred to under the heads alkaline, saline, and neutral waters.

The alkaline Bell zone water has been found principally on the northern flank and near the top of the structure. It is characterized by its low primary salinity content, 44 per cent, with a correspondingly high carbonate chloride ratio. It is distinguished from the Foix water by its lower primary salinity, higher primary alkalinity, lower alkaline earth content, higher carbonate chloride ratio, and usually a higher concentration. It is easily distinguished from the Meyer water by its lower concentration, lower primary salinity, higher primary alkalinity, and higher carbonate chloride ratio. It may be distinguished from the other Bell waters by its lower primary salinity, higher primary alkalinity, and higher carbonate chloride ratio.

The saline Bell zone water has been found principally on the outer edges of the Bell zone and on the southwestern flank of the structure. It closely resembles the Meyer zone water and in some samples it has been difficult to differentiate between it and the Meyer water. It is distinguished from the Foix water by its higher concentration, lower alkaline earth content, and higher primary salinity. From the other Bell waters it may be distinguished by its higher concentration, higher primary salinity, and lower carbonate chloride ratio. It differs from the Meyer water by its lower concentration, lower primary salinity, and higher carbonate chloride ratio.

The neutral Bell zone water is one which falls between the other two classifications and usually has about an equal percentage of

primary salinity and primary alkalinity. It is, nevertheless, characteristic of the Bell zone water and is probably the most extensive in area. It is distinguished from the Foix water with difficulty. In some cases the only separation can be found in the difference in the content of alkaline earths. The difference in primary salinity and primary alkalinity are also very useful in this differentiation. It is distinguished from the Meyer water by its lower concentration, lower primary salinity, higher primary alkalinity, and higher carbonate chloride ratio. It differs from the other Bell waters in that it is an average of the extremes and accordingly is placed in the neutral group.

The Meyer water is an altered connate water with the highest concentration of dissolved salts in the field. It has been more uniform in its analyses than the Bell waters. The Meyer water has been encountered in the outer regions of the producing zone and also near the top of the structure below 4,800 feet. In the southern portion of the producing area water has been encountered in a number of wells below 4,700 feet. The principal characteristics of the Meyer water are its high concentration of dissolved salts, high primary salinity, low primary alkalinity, and corresponding low carbonate chloride ratio. It is distinguished from the Foix water by its high concentration, high primary salinity, low primary alkalinity, low alkaline earth content, and low carbonate chloride ratio; from the Bell water by its high concentration, high primary salinity, low primary alkalinity, and low carbonate chloride ratio.

The attached table gives the average properties of the different waters analyzed with the distinguishing features marked.

WATERS OF SANTA FE SPRINGS[1]

Waters	No. Samples	Total Salts P.P.M.	NaCl P.P.M.	Reacting Values in Percentage					Primary Salinity	Primary Alkalinity	Secondary Alkalinity	CO_3Cl
				Na	Ca Mg	SO_4	Cl	CO_3 HCO_3				
Foix.......	12	5,000 to 7,000	3,000 to 5,000	46	*4	.05	31	19	60	31	9	0.7
Bell:												
Alk.>Sal.	21	7,000	2,600	48	2	.10	22	28	*44	*52	4	*1.3
Alk.=Sal.	12	7,000	3,500	48	2	.15	25	25	*50	*47	3	*1.0
Alk.<Sal.	46	8,000	6,000	48.5	1.5	.15	37	13	*75	*23	2	*0.5
Meyer......	24	*10,000	*9,000	48	2	.15	46.5	3.5	*93	*3	4	*.08

* Principal distinguishing features.

[1] None of waters show any secondary salinity.

DISCUSSION

C. M. WAGNER: I am firmly convinced that the Santa Fe Springs field will ultimately produce an additional 50,000,000 barrels of oil from the known productive zones and will eclipse all records for production per acre from the entire field. It might be well to bring up some phases of the water problem since the future daily production may be affected. Out of the total field production of 340,000 barrels per day at the present time (September 20, 1923) 325,000 barrels come from the Meyer zone and but 15,000 barrels are produced from the Bell sand. Although the average for the field per well of 1,750 barrels per day is considerably below the peak of 2,200 barrels per day, the figure is still impressive and hardly suggestive of the fact that already 28 wells out of a total of 180 wells are producing water in damaging amounts from the zone from which over 95 per cent of the field's production is drawn. In addition to those wells on the production list, approximately 15 per cent of the drilling wells are encountering some stage of the water problem. What, then, is the real stage of the water problem in the Meyer zone and how seriously can it affect the field production?

Differentiation of the various field waters in accordance with chemical characteristics has made possible an understanding as to the manner in which edge waters have encroached on the Bell sand. Obviously, since the encroachment is continuing to take place from all sides, it is useless to go into details regarding conditions existing at any particular time, other than the manner in which the problem has worked out in one zone and the probability of the story being repeated in the lower zone. Since the discovery, or rather rediscovery of the Meyer zone in August, 1922, 60 Bell sand wells have been deepened to the Meyer zone, practically all of which followed that course on account of water in damaging amounts in the upper zone. In other words, under the intensive drilling campaign, in less than two years nearly twice as many producers from the Bell sand have been ruined by the encroachment of edge water as are now producing from that zone—that is 33.

Early this year and before the situation in the Bell sand had become serious, careful subsurface work and core drilling demonstrated the presence of water in the base of the zone at a point very close to the apex of the structure. At such a location the water had the physical characteristics of an intermediate water but in chemical character was identical with the edge waters of the Bell sand, and in addition was not separated by an impervious shale break from the oil production above. Considered as a unit, the Bell zone, 325 feet in thickness, is composed of 250 feet of oil sand in the central portion of the field and 75 feet of barren water sand, the water level existing as a plane throughout the field, slightly tilted or concave upward at the border of the zone, and originally to be found at a depth of 3,900 feet. During the last year the plane has been rapidly rising and has taken well after well not only about the edge of the zone but also those wells near the center of the pool which were drilled too deep.

The maximum productive penetration of the Meyer zone amounts to 740 feet, although from its physical character of alternating sands, sandy shales, and sticky shales the entire thickness can not be considered as a unit. In various wells bottom or edge water, similar in type and occurrence to that at the base of the Bell zone, has been found near the center of the pool at approximately 4,800 feet, and in all probability likewise exists as a plane slightly tilted upward at the borders of the zone. In addition to this lower plane cutting horizontally across the folded productive strata, top members of the zone go to edge water concurrently with the lower members. The greatest productive area is not found at the top of the zone, as is the case with the Bell, but rather within the middle portion of the zone. With these two factors to contend with operators face a more serious situation in the deeper zone than existed after the discovery of the limit of drilling in the Bell zone.

During the early stages in the development of either sand initial production and production per well have been held up and increased by successively carrying each well deeper. When this could no longer be done in the Bell sand and operators were forced to finish up wells at a shallower depth on account of the rising water table, production in the zone rapidly declined from a maximum of 55,000 barrels per day in February this year to 15,000 barrels per day at the present time. Water has now stopped deeper prospecting in the Meyer zone. Production of the zone is at the maximum and a rapid decline is to be expected within a very short time.

E. L. Estabrook: Are the variations in gravity in the different oil zones accompanied by variations in the chemical character of the edge waters? That is, does the character of the edge water seem to influence the character of the oil? Is the edge water in the Bell zone the same as in the Meyer zone?

R. R. Templeton: There is quite a variation in the gravity of the oil from the same zone dependent upon the location of the well on structure. The gravity of the Foix zone oil ranges from 24.6 to 27.8 Baumé, that of the Bell zone from 25.5 to 32.3, and that of the Meyer zone from 33.8 to 35.9. In all cases the low gravity oils have been found in the lateral edges of the zones and associated with water. I do not know of any peculiar action between the different types of waters and the gravities of the oil. There is a little evidence that points to a similarity in certain areas between the waters from the Bell and Meyer zones.

"BLACK SHALE" FORMATION IN AND ABOUT CHESAPEAKE BAY[1]

MARCUS I. GOLDMAN
U. S. Geological Survey, Washington, D.C.

On account of the importance that clay rich in organic matter may have as a source of petroleum, the various conditions under which it accumulates are of significance to the oil geologist, theories about those conditions sometimes leading to decisions of great economic importance. Though the variety of possible geographic environments under which such sediment may form is coming to be recognized by geologists,[2] additional instances of modern occurrences are of value as helping to broaden the scope of the interpretation of fossil occurrences and to counteract the tendency to "match" sediments; that is, to accept a few modern occurrences that happen to be known as representing the conditions under which all those of the past were formed. It is therefore not intended to claim that the instances to be described are representative of the conditions of "black shale" formation, or even common. I am, indeed, inclined to doubt whether, from the point of view of the petroleum geologist, "black shale" exists as a distinct type. From geological relations it seems more likely that there is a constant gradation in the proportions of the different constituents—plant and animal matter, sulphides, etc. The instances to be described are perhaps exceptionally rich in these constituents. But, in addition to recording another instance, the point it is desired to bring out is that regardless of their duplication geologically, aside, that is, from their specific characters, they illustrate certain general factors which may enter into the formation of any fine sediment containing organic matter.

[1] Published with the permission of the director of the U. S. Geological Survey.

[2] A. W. Grabau, *Principles of Stratigraphy* (1913), pp. 478–79; Pirsson and Schuchert, *Text Book of Geology* (1915), pp. 493–94.

The following account is based on the studies of the United States Bureau of Fisheries.[1]

The Bureau's attention was drawn to these occurrences by two reports—one of unusual mortality of fishes near the mouth of Potomac River, the other of an unusual mortality of oysters on the west shore of Chesapeake Bay near Dare's wharf and the mouth of Patuxent River, about midsummer 1916.

The occurrence near the mouth of the Potomac will be taken up first as it has been studied somewhat more in detail. An investigation of that region disclosed that in a large "hole" or depression in the bottom of the Potomac near its mouth there was an accumulation of black mud rich in organic matter which was foul smelling and liberated hydrogen sulphide. The combination of factors that may have particularly favored the development of these black muds at the mouth of the river is outlined by Doctor Almy as follows: (1) the presence of a deep hole; (2) the washing to and fro by the tide of material in the adjacent shallower portions, which tends to accumulate the finest and lightest sediment, of which organic matter is a large part, in this hole; (3) the slowing of the river current as the river widens at the mouth and enters Chesapeake Bay; and (4) perhaps to some extent the flocculation of finely divided suspended organic matter by the greater salinity of the water of the bay just as fine mud is precipitated when it passes from fresh to salty water. Doctor Almy believes, however, that most of this flocculation occurs much farther up the river.[2]

Doctor Almy expresses the opinion that vegetal matter is present in these muds in small amount because it decays more slowly than animal matter, and, therefore, would tend to be concentrated, and

[1] Unpublished manuscript by H. F. Taylor and L. H. Almy, which the Bureau was kind enough to lend the present writer.

[2] For further field observations of the relation of turbidity to salinity in the Potomac River and Chesapeake Bay see: J. N. Sale and W. N. Skinner, "The Vertical Distribution of Dissolved Oxygen and the Precipitation by Salt Water in Certain Tidal Areas," *Jour. Franklin Inst.*, Vol. 184 (1917), pp. 837–48.

Kraus makes the interesting suggestion that some accumulation of organic matter at the meeting of fresh and salty water may result from destruction of microflora and microfauna as a result of the sudden change of environment. Maximilian Kraus, "Oil Deposits and the Tectonics of Vertical Pressure," *Jour. Instn. Petrol. Technologists*, Vol. 9, No. 38, p. 282. London: August, 1923.

a microscopical examination should reveal the presence of cellulose fibers. Yet no fibers could be detected in any of the samples of mud examined. A mere microscopical examination, however, without preliminary treatment cannot be regarded as conclusive on this point.

In the "hole" the circulation of water is slow, hence its oxygen is soon depleted,[1] anaerobic bacteria develop freely, and, as pointed out by Almy and Taylor, conditions are favorable for the carbonizing[2] and desulphurizing processes characteristic of the anaerobic decomposition of organic matter.[3]

A probable source of some of the hydrogen sulphide liberated by muds rich in organic matter is the decomposition of amino acids, some of which contain sulphur and tend to yield hydrogen sulphide on decomposing. Doctor Almy, in his unpublished manuscript, states that the ease with which bacteria can evolve H_2S from proteins is due in large part to the thio-group of the amino acid cystine, one of these sulphide-bearing amino acids, which is said to be present in most proteins to a greater or less extent and to be the most insoluble of all the amino acids. On account of this insolubility he suggests that it would tend to accumulate in the mud. This idea needs experimental verification as the amino acids react readily and tend to combine with other organic compounds.

The occurrence of black mud at the mouth of the Potomac is not unique in the general region of Chesapeake Bay. Similar black muds have been found near the mouths of Rappahannock and Patuxent rivers; and in the Potomac itself, above the mouth, not only are there similar bottom depressions or "holes" but in the deepest parts of the river generally there is an accumulation

[1] For evidence on the effect, on vertical circulation, of under-run of salt water, that is, of salinity stratification of water in the Potomac regardless of temperature or form of bottom, see paper by Sale and Skinner cited.

[2] Carbonizing is usually considered to be the reduction of an organic compound toward carbon as the ultimate end-product. The formation of oil probably takes place along other lines of chemical change which may occur in anaerobic decomposition.

[3] For a review of the processes, see David White and Reinhardt Thiessen, "The Origin of Coal," *U. S. Bureau of Mines Bull. 38*, 1913; and E. C. Harder, "Iron-depositing Bacteria and Their Geologic Relations," *U. S. Geol. Survey Prof. Paper 113*, especially pp. 40–44.

of organic matter containing sulphides. According to Mr. Radcliffe,[1] of the Bureau of Fisheries, black muds are also found generally along the west side of Chesapeake Bay in a band between the sandy, near-shore deposits and the better-scoured central channel. Doctor Almy, on investigating the death of oysters in this region in 1916, found that the mortality was always associated with the muddy bottom, as against clear, sandy, or rocky bottoms. The prevalence of these muds on the west shore of the bay he thinks may be due to the tendency of currents in the Northern Hemisphere to swerve to the right, as explained by Eakin.[2] In support of this theory, the Bureau has found that in the streams feeding into Chesapeake Bay and in the mouth of the bay, outgoing fresh water tends to be on the right side and incoming salt water on the left. While this may be a factor, it seems likely to me that the greater drainage area of the streams on the west side and differences in the vegetation and physiography of the country drained by them are the controlling causes of this distribution of the muds.

Almy suggests as possible causes of the mortality of oysters on these mud bottoms: (1) unusual liberation of toxic substance by the bacteria in the mud; (2) unusual reduction of oxygen by these bacteria; (3) stirring up of the mud, possibly by unusual bacterial action, or (4) by storms, resulting in burial of oysters by mud. (5) The excessive bacterial activity, he thinks, may have been due to a period of high atmospheric temperatures.

The association of larger amounts of organic matter with the finer inorganic sediments is worth noting. It may be due, in part, to original sedimentation; in part, to a protective effect of the inorganic mud leading to slower oxidation.

According to Radcliffe,[3] these muds in the bay proper for the most part lacked the noticeable odor of hydrogen sulphide found in the Potomac River muds, although the areas in which they occurred had the discouraging effect on animal life just discussed. This scarcity of hydrogen sulphide, if on further study it proves

[1] Oral communication.

[2] Henry M. Eakin, "The Influence of the Earth's Rotation upon the Lateral Erosion of Streams," *Jour. Geol.*, Vol. 18 (1910), pp. 435–47.

[3] Oral communication.

genuine, indicates that even within this limited region there are factors modifying the relative development of the different decomposition processes involved.

Some of these modifying factors have been considered by Dctoor Almy in his manuscript. Among them are temperature as affecting especially the activity of bacteria but also affecting purely chemical reactions; chemical composition of the water, as, for instance, its content of inorganic sulphur compounds from which some of the sulphides may be derived; nature of the organic matter; perhaps the amount of sunlight; etc.

The occurrence of organisms higher than bacteria associated with the deposit of black mud at the mouth of the Potomac has not been reported, nor is anything said about forms associated with the oysters on the west shore of Chesapeake Bay, but certain characteristics of the higher fauna commonly noted in occurrences of black shales of past ages are as inherent accessories to the accumulation of dead organic matter as the anaerobic bacteria themselves. Such are the scarcity of littoral or benthonic forms; thinness of shells which, as pointed out by Schuchert[1] and Walther,[2] are normal results of unfavorable biological conditions; dwarf forms;[3] predominance of a few species; and the replacement of shells by iron sulphide, a natural outcome of the frequently abundant production of sulphide under these conditions.[4] In this connection, the special problem which led to the investigation by the Bureau of Fisheries, the sudden mortality among fishes and oysters at the mouth of the Potomac and in Chesapeake Bay, is also significant.[5] Almy's suggested explanations for the phenomenon have been mentioned above. Here is a parallel and an explanation for the scattered layers rich in organisms that are said to be characteristic of many black shales, the fish layers, for instance, in the Mansfeld

[1] Pirsson and Schuchert, *op. cit.*, p. 494.

[2] Johannes Walther, *Einleitung in die Geologie*, Vol. 1 (1893–94), pp. 65, 66.

[3] It was noted by the Bureau of Fisheries investigators that the oysters on the muddy bottoms were less well developed than those on hard bottoms.

[4] Harder, *op. cit.*

[5] There is reason for believing that fat bodies like those of fishes and oysters would be particularly good sources of petroleum.

slates of Germany. It has always been difficult to account for the abundance of these organisms in an environment which was unfavorable enough to kill them off in such large quantities; and such assumptions have been offered in explanation as that they wandered by mistake into an inclosed body of poisonous water and were killed off, or that there were sudden discharges of poisonous volcanic gases. In the occurrence at the mouth of the Potomac and its interpretation, we have an explanation that is much simpler and more normal, and, therefore, more in conformity with the uniformitarian trend of geology.[1]

Of the four factors enumerated by Almy as possibly contributing to the accumulation of organic matter near the mouth of the Potomac, the geologist would perhaps be inclined to pick out, as particularly significant, the presence of a "hole," a depression in which, because it lies below the level of the surrounding bottom, circulation is greatly reduced, and oxygen in the water consequently depleted. The geologic significance of this factor lies in its similarity to the well-known conditions in the Black Sea,[2] and in the indication at the same time that certain essential conditions among these are likely to be reproduced under many otherwise very different physiographic environments. But out of a complex of interrelated factors leading to a certain result, one may not segregate one and say: "This is the essential one." If there were not other factors favoring the accumulation of organic matter, the reduction in the rate of oxidation might not be sufficient to permit of its preservation. And this leads to the recognition of the more fundamental condition underlying all accumulations of sediment rich in organic matter, that they represent the product of an equation between the rate of supply of organic matter and the rate of decomposition. In some cases, as in that of the Black Sea, or the first of those described above, stagnation and consequent reduction in the rate of oxidation is the most unusual factor; in others, as in that described by Twen-

[1] In this connection see also Harden F. Taylor, "Mortality of Fishes on the West Coast of Florida," *U. S. Bureau of Fisheries Document 848*, 1917.

[2] N. Androussow, "La mer noir," *Guides des excursions du 7me Congr. Géol. Internatl.* (1897), No. 29.

hofel[1] or the second of those described above, unusually rapid supply of organic matter may be the larger component of the equation. But each component is essential, and the conditions that produce each of them may be so varied that "black shales" are likely to be formed under a great variety of environments. All occurrences have many features in common, though developed in different proportions; if all the same processes do not participate in the formation of all deposits at least there are pretty certain to be continuous series from each extreme type. So that differentiation of types by single index characters is not likely to be possible. Differentiation is further made difficult by the fact that the evolution of the deposits, even beginning with their decomposition, and still more in their metamorphism, tends to make them similar.

Since, then, no single character will probably suffice to differentiate one deposit of black shale from another, to determine whether it was formed in an isolated salt-water basin like the Black Sea, in a shallow, swampy region like some of the shores of the Baltic, in an estuary like Chesapeake Bay, in a great inland lake like ancient Lake Lahontan in Nevada,[2] or in one of the many other geographical environments in which muds rich in organic matter have been and doubtless will be found, dependence must be placed for their differentiation partly on the degree in which the different features are developed, partly on associated organisms, and more especially on accompanying geological characteristics such as they do not all share.

[1] W. H. Twenhofel, "Notes on Black Shale in the Making," *Amer. Jour. Sci.*, Vol. 40 (1915), pp. 272–80.

[2] In a well drilled by the U. S. Geol. Survey to a depth of 1,500 feet in the Black Rock Playa, Nevada (part of the bottom of this extinct Lake Lahontan), there were encountered an actual shore-swamp peat and two types of black mud, one evidently owing its color to organic matter, which did not fade on exposure to the air, the other evidently colored by the monosulphide of iron which turned pale green on exposure to the air but could be made to resume its black color by exposure to hydrogen sulphide gas.

NOTES ON NATURAL GAS FIELDS OF TRANSYLVANIA, RUMANIA

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INTRODUCTION

Little attention has been paid by American geologists to European oil or gas fields; and this circumstance, together with the bearing of conditions in Transylvania on certain of our own fields, has prompted the writing of this paper. The fields of Transylvania have come to the attention of European geologists from time to time through the writings of Mrazek, Böckh, and others, but little literature has been available in the English language, so that few comparisons have ever been made with American fields. The purpose of the present paper is to point to a parallelism with our Gulf Coast fields which will outline certain particulars common to all salt dome fields and worthy of widespread discussion.

Acknowledgment is made to Professor Hugo Böckh for abundant data and guidance through the fields, to Mr. Francis Böhm for statistical information, to many officials of the pre-war Hungarian Government for facilities and courtesies rendered, and to Mr. Alten S. Miller for the opportunity to make the investigation and for helpfulness in field discussions relative to measurement of the capacities of wells and other matters.

PRIMARY GEOGRAPHIC CONSIDERATIONS

While the province of Transylvania has suffered great vicissitudes, and while the race, religion, and constituency of its inhabitants are highly complex, it is fully as interesting geographically as politically. Rumanians living in the province find themselves on the opposite side of a high mountain range, the Transylvanian Alps, from that of Rumania proper; thus one need not wonder that the people have been governed by Hungary for so many centuries. The mountains which lie between Transylvania and

Rumania proper swing to the east and then north and form the Hargita Mountains on the frontier of the Bukowina; thence they continue northwest into the Carpathians proper, which continue northwest for 400 miles near the southern boundary of Poland. Thus, on account of the great curve of a single mountain range, the province of Transylvania forms a perfect basin, closed on its western side by the Ore Mountains. The basin of Transylvania may be likened to the Big Horn Basin of northern Wyoming, in its size, physical and economic geography, as well as in topography, geologic development, and stratigraphy, although the comparison should not be extended to the types of structure and the sequence of geologic formations.

The Transylvania Basin comprises about 7,700 square miles, lying between the Hargita Mountains on the east, Transylvanian Alps on the south, Ore Mountains on the west, and smaller ranges on the north.

From Kolozsvár, in northwestern Transylvania, to Brasso, not far from the base of the South Carpathians, the distance is about 125 miles in a southeasterly direction, and the transverse diameter of the basin is nearly as great. The valleys of Maroz, Kukullo, and Alt rivers are comprised in the basin. Roughly, the basin occupies the region between Sajo River on the north and the Alt on the south; its western boundaries lie in the vicinity of Kolozsvár and Oyula-Fehervah, while the eastern border extends to the foothills of the mountains.

STRATIGRAPHY

The formations of the Transylvania Basin are mainly of Tertiary age and they may be classified as in Table I.

The total thickness of formations in the Transylvania Basin is many thousand feet, and each of the formations above may comprise a thousand feet or more. No exact measurements are known to the writer. Some of the sands of the Upper Mediterranean formation, like those of the overlying Sarmatian, are suitable for the retention of natural gas, and gas will probably be found in them. Practically all the gas produced in Transylvania has come, however, from the Sarmatian formation, in which sands, clays, and marls predominate. The Upper Mediterranean formation contains a vast amount of very

finely divided sodium chloride, and is called by European geologists the "saliferous Miocene." This saliferous character is significant in view of the existence of numerous salt domes in the Transylvania Basin.

TABLE I

PERTINENT STRATA IN TRANSYLVANIA

Series	Formation	Character and Productivity
Pliocene	Panonian (Pontian)	Sands and clays. Presence of natural gas is not known in large quantities.
Miocene	Sarmatian	Sands, clays and marls. Practically all the gas produced in Transylvania comes from this formation.
	Upper Mediterranean	Clays, sands and marls. Believed favorable for gas, but not known to have been tested.
	Lower Mediterranean	No gas known.
Oligocene		Gas not believed to exist in commercial quantity.
Eocene		Gas not believed to exist in commercial quantity.

OCCURRENCE OF THE GAS

All gas produced on a commercial scale in the Transylvania Basin is derived, according to latest information of the writer, from the Sarmatian formation, in which it occurs in fine-grained sandstones, sands, sandy clays, and marls. The demarcation between various members is not always distinct, but they generally grade into one another, so that no driller can say with certainty where a particular sandy stratum begins or ends. Consequently strata of all degrees of productivity are found; and the upper portion of the well frequently shows only traces of gas at low pressure, while deposits of high pressure and large volume exist at greater depths. Since the Upper Mediterranean sediments are similar in character to the Sarmatian, geologists predict that gas will also be found in that formation. Gas is not known to have been found in the Panonian in commercial quantities, but there is reason to suppose it will be found there.

GEOLOGIC STRUCTURE

While Transylvania consists broadly of a great structural basin, it contains nearly a hundred local uplifts in the nature of domes and anticlines. West of a line from Dós to Kolozs, Torda, Nagy-Enyed, and Vizakna the strata are greatly disturbed, and all gas is supposed to have escaped. For a similar reason, no gas in quantity is expected east of Szász-Régen, Szováta, and Kohalom. The few anticlines are confined to localities near the margins of the basin, while the domes are distributed throughout the basin in several series parallel to the bordering mountains. The domes may be classified as follows:

CLASSIFICATION OF TRANSYLVANIA DOMES

(1) "Closed domes" (closed both as regards contour and also in the sense of having a salt core entirely covered by Tertiary sediments.)
(2) Domes penetrated by masses of rock salt.
(3) Domes penetrated by masses of basaltic rock.

1. *Closed domes.*—All natural gas known by the writer to have been produced in Transylvania has come from closed domes. While in some cases the ordinarily productive formations have been removed by erosion, in most of them the Upper Mediterranean, and in many of them the Sarmatian formation, is present. Geologically the closed domes are simply brachy-anticlines or somewhat elongated domes, with the major axis seldom over $1\frac{1}{2}$ or 2 times as long as the minor axis, but in a few instances 3 times as long, as at Mezö-Zah. The ordinary dip away from a closed dome is from 2 to 15 degrees. The formation in the center of these domes is generally of Sarmatian age, but may be of Panonian or Mediterranean age. The dips of the Miocene sediments on the flanks range from nothing to 30 degrees or higher and even 90 degrees in places, and the steepest dips exist where the Mediterranean formation occupies the surface.

In six of the closed domes natural gas has been found by drilling, viz., at Sármás (Fig. 1), Mesö-Sámsond, Mezö-Zah, Magyar-Sáros, Bázna, and Schemert. Nearly forty closed domes exist which are not known to have been tested. The area of a single dome is from 4 to 36 square miles.

2. *Domes penetrated by masses of rock salt.*—Little difference can be observed between domes of classes 1 and 2 aside from the fact that the latter are penetrated by great masses of rock salt which have been intruded from below. The breakings and steep dips surrounding some of the domes of Class 1 suggest that no real dis-

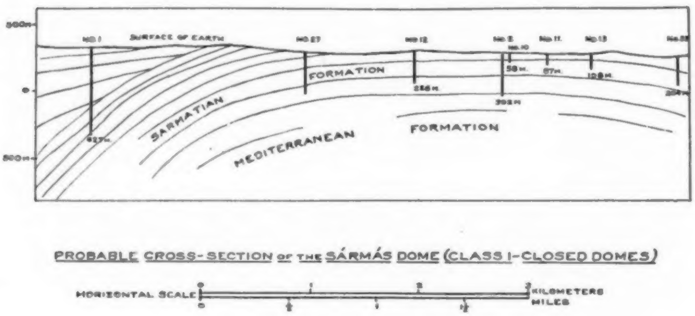

FIG. 1

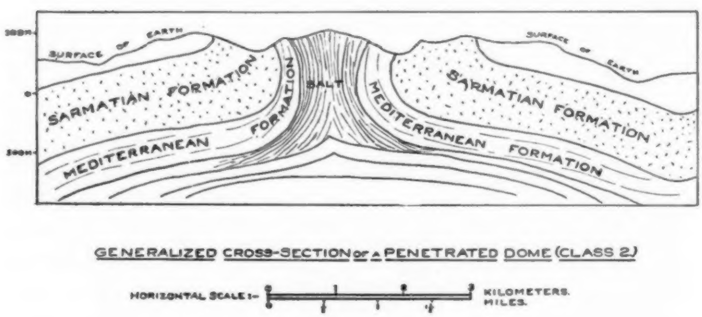

FIG. 2

tinction in structure exists between the two types, but that salt also exists under all domes of Class 1. A cross-section of a penetrated dome is given in Figure 2.

At Kolozs, Szováta, and Parajd the salt can be seen outcropping at the surface of the earth. In at least sixteen of the Transylvanian domes rock salt occupies the surface or is known within a few feet

of it, while in eight domes the salt is mined or has been mined extensively below ground.

In some cases, as at Vizakna, Szováta, and Kolozs, the salt masses, with attendant saline waters, are utilized for baths at summer resorts. In several instances, ancient salt mines occupying the domes date back as early as the beginning of the Roman occupation. Some of the masses have been proved over 600 feet thick and over half a mile in diameter.

3. *Domes penetrated by basaltic rock.*—Only one example is known of a dome penetrated by rock, namely, that of Köhalom, in which basaltic rock forms the high crest of a hill on which stand the ruins of the ancient Köhalom castle. Little difference was noticed between the structure of this and the salt domes, but the dips surrounding the basaltic core are not known with certainty to be as great as those surrounding many salt masses. Although no other basaltic intrusion is known in any of the domes, similar rock outcrops in the mountains between Köhalom and Brasso.

Anticlines.—In the Transylvania Basin several anticlines exist in which the rocks are highly folded, but in which distinct domes have not been mapped. The most conspicuous anticline known to the writer is that of Sorostély.

NATURAL GAS WELLS

At the time the first well was sunk for potash in 1908, the strata in the Transylvanian Basin were believed to lie flat and domes were unknown. Drilling in Transylvania was commenced in 1908 and the first well was completed in April, 1909. The cost of the wells was from less than $5,000, in the case of a 400-foot well, to over $35,000 for some failures 3,000 to 4,000 feet deep. The greatest depth reached was 4,280 feet at Maros-Ugra in Kis-Küküllö County. Of the first eleven wells drilled, nine were dry holes, one was an artesian water well, and only one was a gas well. Numbers 1 and 2 were not drilled for gas, but with the expectation of finding potash.

In well No. 2, however, natural gas was encountered, causing a revision of the program. Following this discovery seven wells were drilled in the vicinity of large towns widely separated, in none of which localities was the geology favorable. The futility of hap-

hazard drilling having then been demonstrated, the balance of the wells were drilled on domes. From 1908 to 1913, nineteen wells of commercial volume were brought in from 200 to 1,200 feet deep. The fact that eighteen successive good wells were obtained in domes after ten failures had been drilled off structure is a sufficient testimonial to the geological work done by Dr. Böckh and his assistants.

The initial rock pressures ranged from 120 to 460 pounds per square inch, but the pressures are not directly proportional to depth of well. In fact the gas-bearing strata are so irregular in position that the gas cannot be said to come from definite horizons or "sands." The open flow capacities of the wells range from less than a million to over 30,000,000 cubic feet per day. It is important to remember that the gas is derived from a great number of different strata, with different volumes and pressures, and that existing wells, even in the same dome, seldom tap identical lenses.

SÁRMÁS GAS FIELD

The best known of the Transylvania gas fields is situated just northeast of the villages of Kis-Sármás and Nagy-Sármás, in Kolozs County. For over 200 years gas exudations have been known in the vicinity of Kis-Sármás, not far from the crest of the dome, which is now the most extensively developed of any of the Transylvanian domes. The area of this dome is estimated at 4 square miles. The surface formation is Sarmatian, and the same formation exists to the bottom of the wells, one of which is 1,920 feet deep.

The first well was abandoned as a failure at 2,050 feet. The second well was the famous Sármás No. 2, only 992 feet in depth, which proved an enormous gas well. The original rock pressure at the bottom was 384 pounds per square inch. Owing to inexperience with gas field methods, difficulty was experienced in closing the well. A commission headed by Mr. Francis Böhm was sent to America to investigate ways and means, and on his return in June, 1910, the well was successfully closed.[1]

By this time gas was escaping from the earth at many places within a radius of 1,000 feet from the well, having forced its way to the surface through the imperfect packing at the 430-foot gas horizon, and the laborious method of pumping the space outside of

[1] Böhm, Ferenc: A Kissármasi Gáskut Tomitése, in "A Magyar Mérök-es Epitéz-Egylet Közlönye," Evf. 7, Számábel, Budapest, 1912.

the casing full of "cement milk" was resorted to in order to save the well and the field.

From the time of successfully sealing the sands in July, 1911, until the end of October in the same year the well was closed continually, but on October 26 a severe shock occurred, followed by a second and third shock on the morning of October 29. At 2 A.M. the well guard heard a heavy rumble and at 2:30 o'clock came the severest shock, at which time débris was thrown into the air at a distance of half a mile from the well, and gas commenced to leak in many places from an area of several acres. The shock was felt in an elliptical area about 5 miles in length along the major axis of the dome.

Gas blowouts have been so frequent in America that a detailed description of an individual case might be supposed superfluous; but the Sármás incident has occupied so much space in Middle European scientific literature that a record of the above is important in a description of this interesting field. Strange to say, much controversy existed at the time between Hungarian geologists as to whether the shock was caused by escape of the gas or whether it resulted from an earthquake. Böckh and others have told the story carefully and authentically in Hungarian scientific publications.[1]

QUALITY OF THE GAS

Transylvania natural gas is of high quality for a dry gas. Some analyses made in the laboratory of the Hungarian Government at Kolozsvár are taken from and so far as known, unpublished manuscript of Dr. Hugo Böckh.

SURFACE INDICATIONS OF GAS

Gas springs.—As is the case in many gas fields in younger formations, seepages constitute the best evidence of the existence of gas. Exudations have occurred for 200 years in the center of the Sármás dome and on the Magyar-Sáros dome. One of the last mentioned is situated midway between the villages of Vámos-Galfalva and Bogács, and is one of the largest exudations of gas known in Transylvania. About 100 years ago a commission was appointed to consider the advisability of piping this gas to the village of Magyar-Sáros.

[1] Bányászati es Kohaszati Lopok, XLV evfolyan 1 kötel, 2 szóm, Budapest, January 15, 1912, pp. 65–103.

At that time the spring was known as a "roaring spring," and the sound can still be heard faintly. Recently the gas has been experimented with for use in a hotel, and is constantly burned in a flambeau. Emanations of gas were also known in the Schemert dome before the actual discovery of gas by drilling. In one case, in the bottom of a subterranean salt mine at Maros-Ujvár, a small amount of gas, consisting of methane and hydrogen sulphide, bubbles up through a three-inch diamond drill hole in the floor.

TABLE II

ANALYSES OF TRANSYLVANIA NATURAL GASES

	Sármás (No. 11)	Sármás (No. 2)	Schemert (No. 22)	Mezö-Záh (No. 29)
Methane	99.10	99.0	97.90	97.46
Heavy carburetted hydrogen	....	....	0.81	2.10
Hydrogen	....	0.4	....	....
Oxygen	0.54	0.40	0.79	....
Nitrogen	0.36	0.20	....	0.44
Carbon dioxide	....	....	0.50	....
Total	100.00	100.00	100.00	100.00
Calories	8489	8530	8716	8637

Salt springs.—Another surface evidence of gas in the Transylvania Basin consists of numerous springs of saline water. Several of these exist near the Mezö-Sámsond dome, and between the villages of Bázna and Balázstelke near the northern end of the Bázna dome. Near the south end of the Sáromberke dome a so-called dry hole was drilled in 1911, and a trace of gas bubbles through a large quantity of salt water, which is allowed to flow through a pipe a few hundred feet long to supply the salt baths of Szent-György. In the extreme southern end of the Szamos-Ujvár dome the baths and mineral springs of Kero are situated. Throughout Transylvania slight emanations of salt water are located by the presence of *Salicornia herbacea* and several other less common species of plants.

Hydrogen sulphide springs.—A supposed indication that the writer is inclined to question is the presence of hydrogen sulphide in water. Nevertheless, hydrogen sulphide gas is found in springs in the vicinity of the Mezö-Sámsond dome, and in another place, in the bottom of a salt mine, a small spring was seen strongly impregnated with that gas.

Mud volcanoes.—The importance of mud volcanoes as an evidence of gas may likewise be doubted by many; but in Transylvania no question exists that mud volcanoes do indicate the position of productive domes. For instance, from one mile south of Mezö-Sámsond, a line of several minute mud volcanoes extends along a valley in the center of which is situated a mud hill 15 feet high and 300 feet in diameter. According to the best authorities this hill did not exist seven years ago, but has risen above the valley during that time. Near the west end of the Schemert dome a small mud volcano is in continual action, and its bubbling is audible for some distance. Small mud volcanoes also exist in the vicinity of Ol-Nadas and Hétbukk, but these are not known to be associated with any dome. Others exist near the anticline of Sorostély. Some minute mud vulcanoes are found in the valley at the south end of the Betlen-Szent-Miklos dome inside the village of the same name, where they cover several acres, but are not elevated above the general surface. At Bázna a tufaceous deposit exists which may be called a fossil mud volcano; it is not now active but rises behind the bath houses to a height of 30 feet from the valley floor.

Several extinct mud volcanoes exist about a mile northeast of Ladamos and they are the largest seen in Transylvania. One of them rises about 23 feet above the river plain, has an average diameter of 250 feet, and in the top of it a crater 3 feet in diameter contains a small spring of water.

CONCLUSION

The domes of Transylvania have been found to have the following characteristics: (1) The stratigraphy is similar to that of American salt domes. (2) Structure is similar to that of American salt domes. (3) Salt cores are frequently observable. (4) Domes are aligned in several series parallel with border of basin. (5) Salt is generally present near the surface in the border series. (6) Salt is deeper toward the center of the basin than near borders. (7) Oil is absent in the domes, so far as known. (8) At least one dome with a basaltic core occurs. (9) The serial lines are curved. (10) The theories of origin commonly accepted in Europe are quite different from those under consideration in America.

CALIFORNIA OIL PRODUCTION AND RESERVES[1]

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GENERAL STATEMENT

In the petroleum world California has passed, during the last two years, from a position of isolation within the economic province on the shores of the Pacific to one of extremely active, if not menacing, competition with the principal petroleum-producing regions of America. It is probable that those who have not been intimately associated with the progress of the petroleum industry in California will be inclined to appraise California oil production by the results of the flood of high-grade petroleum only recently developed in the town-lot fields of the Los Angeles basin. It should be born in mind, however, that petroleum is California's principal source of fuel and power. Whenever oil production declines, as it naturally will, to a point equal to the long-established and growing demands of the Pacific Coast, the flood through the Panama Canal will be less prominent in the picture and California's most valuable resource will continue to be used, as it was destined to be, primarily for California.

Viewed solely from our own provincialism, the great production of the Los Angeles basin has been revolutionary in character; has placed the California petroleum industry closely upon the borders of disaster; and the method of development, namely, the uncontrollable, in fact enforced, drilling of small property holdings, has shown the futility of attempting conservation where each man is set against his neighbor in a greedy contest to get the lion's share of this mobile resource.

It is not our purpose to make predictions as to when the so-called peak will be reached or of the rate of decline in oil production. Others who have made a particular study of oil production of

[1] Read before the Association at the Los Angeles meeting, September 20, 1923. Manuscript received by the editor, February 6, 1924.

individual fields have furnished data for that purpose. In this paper we have attempted to condense some of the available information on the status of California oil production as a whole, the geographic relationship and economic importance of the various oil fields ot the state, as well as the quantity and quality of their production, and also to bring down to July 1, 1923, the estimates of oil reserves, made by the California Committee of the American Association of Petroleum Geologists, as of July 1, 1921.

OIL PRODUCTION

The principal producing oil fields of California lie within six counties—Fresno, Kern, Santa Barbara, Ventura, Los Angeles, and Orange. The oil fields of Fresno and Kern counties are commonly classed in a group known as the Valley fields; the fields of Santa Barbara and Ventura counties, including also the small production of San Luis Obispo and Santa Clara counties, are grouped as the Coastal fields; and the fields of Los Angeles and Orange counties lie within the Los Angeles basin.

The geographic distribution of petroleum-producing areas in California has not changed greatly during the past twenty-five years. Prospecting and careful geologic study have opened new fields, but no new counties have been added to the six principal petroleum-producing counties of twenty-five years ago. The influences and balances of oil production have shifted considerably, however.

Table I shows the production by counties for 1900, 1920, 1922, and the month of June, 1923, and gives the percentages of the state's production for each county and group of fields.

It is unnecessary to resort to tables or statistics for evidence of the extent to which the Los Angeles basin oil production dominates the situation. However, a glance at the percentages in Table I shows that the proportion of Los Angeles basin production to the state's production has increased from 28 per cent in 1920 to almost 80 per cent in June, 1923. Still, this does not put the Los Angeles basin flood in its proper perspective for either past or future. To do so it is necessary to consider and compare to date total productions of all fields, quantities of proved acreages, and acreage developed.

TABLE I

County	1900 Production (Bbls.)	1900 Percentage of Total	1920 Production (Bbls.)	1920 Percentage of Total	1922 Production (Bbls.)	1922 Percentage of Total	Month of June—1923 Production (Bbls.)	Month of June—1923 Percentage of Total
Fresno	547,960	12.6	15,464,198	14.7	9,265,526	6.7	392,141	1.8
Kern	919,275	21.3	52,120,532	49.3	53,512,157	38.7	3,837,745	16.9
Total valley fields	1,467,235	33.9	67,584,730	64.0	62,777,683	45.4	4,229,886	18.7
Santa Barbara	183,486	4.3	5,982,970	5.7	3,931,155	2.8	259,949	1.2
Ventura	443,000	10.3	2,122,000	2.0	2,933,685	2.1	325,133	1.4
Total coastal fields	626,486	14.6	8,104,970	7.7	6,864,840	4.9	585,082	2.6
Los Angeles	1,722,877	39.9	14,205,000	13.4	49,054,731	35.5	13,992,988	61.7
Orange	254,397	5.9	15,800,000	14.9	19,489,577	14.2	3,859,150	17.0
Total Los Angeles basin	1,977,274	45.8	30,005,000	28.3	68,544,308	49.7	17,852,138	78.7
Grand total	4,319,950	....	105,720,310	....	138,236,490	....	22,667,106	....

The oil fields of California produced 1,720,838,000 barrels of oil to July 1, 1923; an average production of 29,250 barrels per developed acre. On July 1, 1923, there were 113,449 acres of proved oil land in California, a little over half of which has been developed by some 14,242 wells drilled to an average spacing of 4.1 acres per well. At the same date the three gusher fields of the Los Angeles basin, covering 5,471 proved acres, or 5 per cent of the state's total, were producing 72 per cent of the total oil output, with 6 per cent of the total number of producing wells. The average daily production per well for these three fields in July, 1923, was 1,057 barrels. The average daily production per well for all other fields of the state, excluding Huntington Beach, Long Beach, and Santa Fe Springs, was 25 barrels for 8,345 producing wells. In December, 1920, the average daily production per well for the 9,600 producing wells of the state was 33 barrels. In the spring of 1922 it became necessary to shut in some of the producing wells in the older fields of the state to make way for the flush production of the Los Angeles basin. It is estimated that on July 1, 1923, a total of 2,000 producers in older fields had been shut in, representing at the time of shut-down a total average daily production of 100,000 barrels. This does not include the production held back in the three big fields as a result of "pinching in." Table II shows the average daily production per well for each field of the state during June, 1923, total recovery to July 1, 1923, and recovery per developed acre as of July 1, 1923.

The relationship between the entire state's production and the revolutionary contribution made by the three new fields of the Los Angeles basin, as well as the extent to which older production has been forced back, is shown in Figure 1 on page 217, in which the upper graph shows the trend of the average daily production, by months, for all fields of the state, and the lower graph shows the trend of production when that of Huntington Beach, Long Beach, and Santa Fe Springs has been subtracted from the total.

QUALITY OF CALIFORNIA OIL

Prior to 1913 the oil fields of California produced more crude oil heavier than 20° Baumé, rather arbitrarily classified as fuel crudes, than crude of 20° and lighter of the "refinable" crude class,

and until quite recently California has been pre-eminently a fuel oil-producing state.

TABLE II

OIL RECOVERED PER DEVELOPED ACRE TO JULY 1, 1923, FROM CALIFORNIA OIL FIELDS

Field	Production to July 1, 1923	Developed Acreage within Proved Area July 1, 1923	Production per Developed Acre	Average Daily Production per Well June, 1923 (Bbls.)	Year of First Production
Coalinga	268,949,000	10,589	25,400	19	1896
Elk Hills	41,606,000	1,832	22,700	234	1919
Kern River	239,317,000	6,139	39,000	9	1900
Lost Hills–Belridge	49,786,000	3,078	16,200	14	1910
McKittrick	66,144,000	852	77,700	24	1898
Midway	365,779,000	17,831	20,500	35	1901
Sunset	95,077,000	2,811	33,900		1900
Wheeler Ridge	39,000	9	4,340	208	1923
Beverly Hills, Los Angeles, Salt Lake	58,043,000	915†	‡	5	1894
Long Beach	45,544,000	444	102,500	987	1921
Montebello	48,749,000	855	57,000	89	1917
Santa Fe Springs	42,394,000	575	73,700	1,815	1921
Torrance	796,000	165	4,830	189	1922
Whittier	9,673,000	568	17,000	11	1912
Brea-Olinda	98,513,000	991	99,400	31	1897
Coyote Hills	86,829,000	1,534	56,550	25	1912
Huntington Beach	32,012,000	914	35,000	547	1920
Richfield	23,299,000	1,069	21,800	95	1919
Summerland	2,466,000	120	20,550	1	1894
Casmalia, Cat Canyon, Lompoc, Santa Maria	110,926,000	4,828	22,950	26	1902
Ventura–Newhall*	26,416,000	2,115	12,500	20	1876
South Mountain	5,459,000	200	27,300		1916
Ventura–(Ave.)	1,888,000	214	8,820		1917
Miscellaneous	1,134,000	160	7,000	9	1894
Entire state	1,720,838,000	58,808	29,250	85	1876

* Includes Bardsdale, Conejo, Ojai, Piru, Simi, Santa Paula, Sespe, and Newhall.
† Los Angeles omitted.
‡ No data on Los Angeles.

The vast supply of low-gravity crudes from the flush production of Kern River and Coalinga facilitated the growth in the use of crude oil for fuel by western industry. In the days of overproduction, especially critical from 1910 to 1915, fuel crudes sold at 30 to

35 cents per barrel at the well. Such prices and an abundant supply naturally promoted and greatly expanded the markets for fuel oil.

The following tables show the transitions in the production of crude oil below 20° Braumé and above 20° in thousands of barrels for each of the principal producing fields of the state. Graphs of total state production by years, segregating production on the same basis,

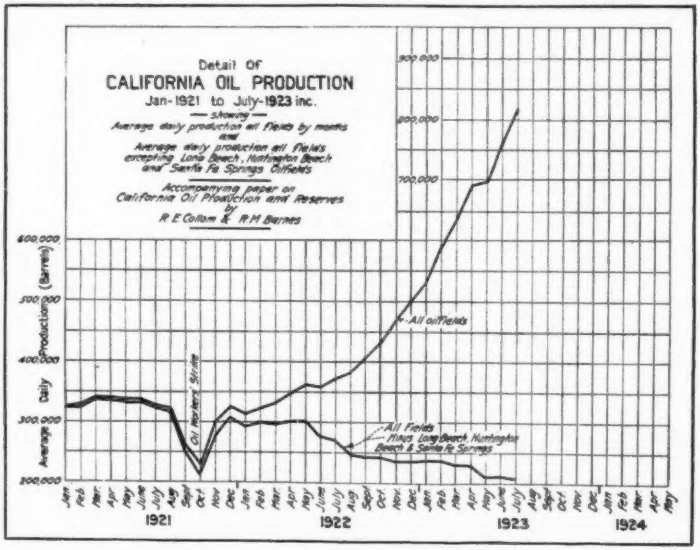
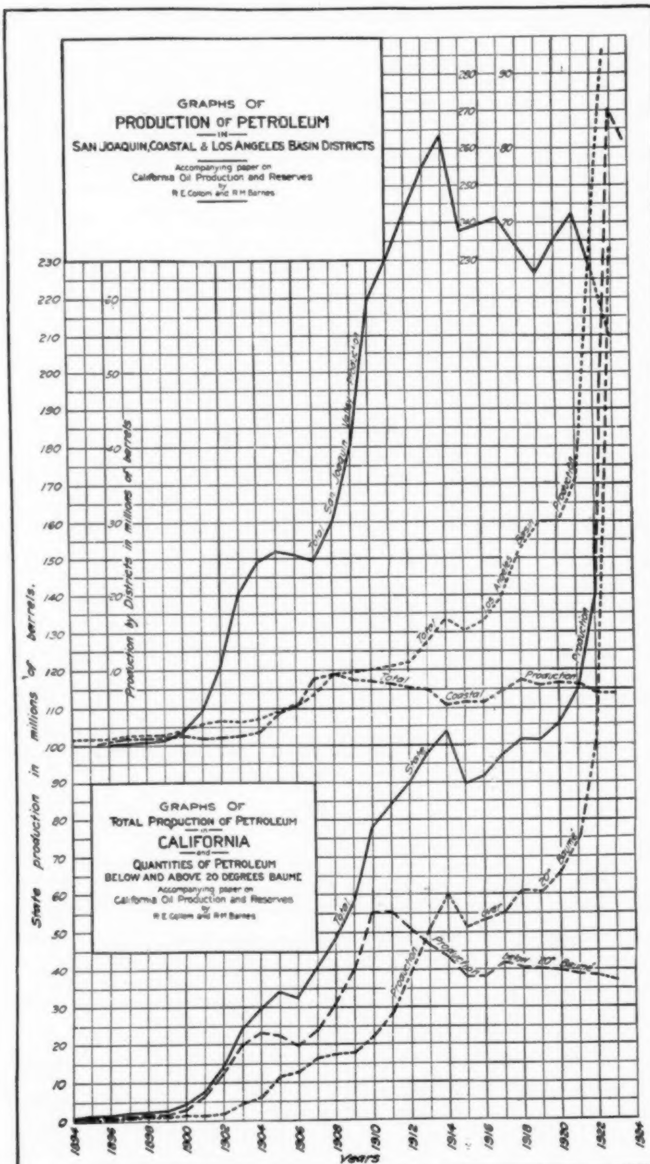


FIG. 1

are shown in Figure 2. In Table XIII are listed the range in Baumé gravities for all fields as of July 1, 1923. These tables, taken together with those which follow, showing proved areas and estimated future productions of reserves, form an interesting basis of study in attempting to determine the future trend in quality of California production.

Following natural declines in the production of heavy oil from fields such as Kern River, Coalinga, and McKittrick, and the increasingly greater demand for refined products, especially gasoline and proper types of lubricating stocks, less crude oil was sold


GRAPHS OF
PRODUCTION OF PETROLEUM
IN
SAN JOAQUIN, COASTAL & LOS ANGELES BASIN DISTRICTS
Accompanying paper on
California Oil Production and Reserves
by
R. E. Collom and R. M. Barnes
GRAPHS OF
TOTAL PRODUCTION OF PETROLEUM
IN
CALIFORNIA
and
QUANTITIES OF PETROLEUM
BELOW AND ABOVE 20 DEGREES BAUME
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State production in millions of barrels.
Production by Districts in millions of barrels
Total San Joaquin Valley Production
Total Los Angeles Basin Production
Total Coastal Production
State Total Production
Production over 20° Baume
Production below 20° Baume
Years

FIG. 2

and used directly as fuel. Refinery residuum was used to supply the market. The Committee of the State Council of Defense[1] estimated in 1917 that "approximately 60 per cent of the oil of the state is now refined in part before being utilized." The committee also stated: "A greatly increased demand for gasoline and lubricants may be anticipated in the future. This increased demand will result in the refining of a large proportion of the oil and a smaller quantity of the crude burned as fuel. Improved methods of refining are being developed which will increase the yield of gasoline and lubricants per barrel of oil treated." It should be noted that these statements were made at the time when the California oil industry was just beginning to recover from the great overproduction of heavy crudes. The time when heavy oil had just ceased to be a "drug on the market" and when the average refinable gasoline content of crude oil was about 8 per cent.

With this historical background we find an exactly opposite condition in July, 1923, with refinable crudes flooding the California oil industry almost to the breaking-point—indeed, if it were not for the Panama Canal, and by its virtue the eastern outlet of 150,000 barrels of crude daily, this western oil industry would be completely inundated with refinable crudes.

As reflected in present published price schedules, all crudes below 20° Baumé are put in one class at one price and gradations in price begin at 20°, the price increasing with the gravity. The Baumé gravity, then, is a rough gauge of the value of the refinable products in a barrel of California crude, or possibly, depending upon the gravity, of its value solely as a fuel, competing with residuum of the refinery. Roughly the rule is applicable, although there are cases where oil of fairly high Baumé gravity is almost devoid of gasoline, such as Montebello crude and the product of the Foix zone at Santa Fe Springs oil field, the latter being 27° Baumé.

As to gasoline content, the crudes of the new fields of the Los Angeles basin compare favorably, and in some instances run higher, in gasoline content than the average mid-Continent crudes. They carry three times as much gasoline as the average refinable crudes to which California has been accustomed.

[1] California State Council of Defense, *Report of the Committee on Petroleum* (July 7, 1917), p. 104.

An estimate[1] of California refinery output for January-May, 1917, when oils principally over 20° Baumé were being refined, showed percentages of refined products as in Table III.

TABLE III

Product	Per Cent
Gasoline—56° Baumé	7.6
Distillates—36°–52° Baumé	7.3
Kerosene—42° Baumé	5.5
Lubricants	1.9
Asphalt and road oil	2.0
Residuum (fuel oil)	75.7

and the following data, taken from tables of Federal Trade Commission[2] of a slightly earlier date, show a comparison of the percentages of refined constituents of California crude with those of Appalachian and mid-Continent crudes.

TABLE IV

Product	Districts			
	California (Per Cent)	Appalachian (Per Cent)	Mid-Continent (Per Cent)	Mid-Continent-Gulf Coast, Mixed (Per Cent)
Gasoline	8.68	20.28	21.05	12.07
Kerosene	8.99	34.87	25.46	15.58
Fuel oil	74.64	9.41	34.52	64.06
Lubricating	1.28	28.98	9.37	1.79
Losses	6.17	4.90	5.81	3.37
Not accounted	24	1.56	3.79	3.13

Improvements in refinery methods, introduction of so-called cracking processes, and reduction in Baumé gravity of gasoline, have increased the proportion of gasoline, in recent years, for refineries operating on mid-Continent and Appalachian crudes, by possibly 10 to 12 per cent, of the total refined products. That is, a mid-Continent crude under present methods of distillation and cracking will yield, say, 31 per cent gasoline as compared with the 20 per cent yield of the 1915 grade of gasoline.

[1] State Council of Defense, *op. cit.*

[2] Federal Trade Commission, *Report on the Price of Gasoline in 1915*, April 11, 1917.

The following are distillation analyses of crude oil from the Huntington Beach, Long Beach, and Santa Fe Springs oil fields:

LONG BEACH CRUDE

Depth................3,300 feet
Gravity at 60° F.....26.3° Baumé
M. & B. S..........1.0 per cent

	Per Cent
Gasoline at 60.0° Baumé..............................	15.5
or	
Navy Special Gasoline at 54.2°........................	21.8

Fractionation

	Degrees Baumé	Per Cent	Degrees Baumé
Tops..................................	52°	27.8	
Slop distillate.........................	37°	1.2	below 52°
Cracking distillate.....................	33°	16.17	below 37°
Furnace distillate......................	25°	11.43	below 33°
Residuum............................	9°	43.4	
		100.00	

SANTA FE SPRINGS CRUDE

Bell zone.......Depth 3,800 feet
Gravity at 60° F.....31.5° Baumé
M. & B. S..........0.4 per cent

	Per Cent
Gasoline at 60° Baumé.................................	17.00
or	
Navy Special gasoline at 55.2° Baumé....................	25.3

Fractionation

	Degrees Baumé	Per Cent	Degrees Baumé
Tops..................................	52	32.5	
Slop distillate.........................	37	6.0	below 52
Cracking distillate.....................	33	20.1	below 37
Furnace distillate......................	29	0.8	below 33
Residuum............................	16.3	40.6	
		100.00	

SANTA FE SPRINGS CRUDE

Meyer zone.....depth 4,500 feet
Gravity at 60° F.....34.7° Baumé
M. & B. S...........0.3 per cent

	Per Cent
Gasoline at 60° Baumé	30.2
or	
New Navy Gasoline	37.0

Fractionation

	Degrees Baumé	Per Cent	Degrees Baumé
Tops	52	51.5	
Slop distillate	37	0.0	below 52
Cracking distillate	33	12.5	below 37
Residuum		36.0	
		100.00	

HUNTINGTON BEACH CRUDE

Bolsa zone......depth 2,900 feet
Gravity at 60° F.....25.0° Baumé

	Degrees Baumé	Per Cent
Gasoline	56.0	16.09
Engine distillate	40.5	10.1
Kerosene	38.5	2.35
Still bottoms	32.0	4.99
Asphalt Residuum	15.3	63.79
B. S. & M		2.68
		100.00

HUNTINGTON BEACH CRUDE

Ashton zone
Gravity at 60° F.....25.5° Baumé

	Per Cent
Gasoline, 53.2° Baumé	17.92
Engine distillate	7.68
Kerosene	4.73
Still bottoms	1.4
Asphalt residuum	66.5
B. S. & M	1.77
	100.00

TABLE V

SAN JOAQUIN VALLEY PETROLEUM PRODUCTION

(in Thousands of Barrels)

Year	Fresno County			Kern County														
	Coalinga			Elk Hills			Kern River	Lost Hills–Belridge			McKittrick	Midway			Sunset			Wheeler Ridge
	Total	−20° Predominating in West-side Field Average 15.6°	+20° Predominating in East-side Field Average 22°	Total	−20°	+20°	−20°†	Total	−20°	+20°	−20°‡	Total	−20°	+20°	Total	−20°	+20°	+20°§
1876–93	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
1894	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
1895	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
1896	14	......	14	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
1897	70	......	70	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
1898	154	......	154	......	......	......	......	......	......	......	10	......	......	......	......	......	......	......
1899	439	......	439	......	......	......	......	......	......	......	15	......	......	......	......	......	......	......
1900	548	......	548	......	......	......	827	......	......	......	80	......	......	......	12	12	......	......
1901	526	25	501	......	......	......	3,279	......	......	......	430	4	4	......	189	189	......	......
1902	571	50	521	......	......	......	8,988	......	......	......	619	3	3	......	168	168	......	......
1903	2.138	288	1,850	......	......	......	16,342	......	......	......	1,353	27	27	......	353	353	......	......
1904	5,098	1,463	3,635	......	......	......	17,226	......	......	......	1,856	1	1	......	390	390	......	......
1905	8,882	2,132	6,750	......	......	......	15,254	......	......	......	1.373	19	19	......	419	419	......	......
1906	8,401	2,011	6,390	......	......	......	12,825	......	......	......	681	12	12	......	308	308	......	......
1907	8,996	2,816	6,180	......	......	......	12,346	......	......	......	2,416	150	150	......	705	705	......	......
1908	10,726	4,081	6.645	......	......	......	13,804	......	......	......	3,076	435	435	......	1,464	1,464	......	......
1909	15,407	7,632	7,775	......	......	......	14,508	......	......	......	5,807	2,234	2,234	......	2,000	2,000	......	......
1910	18,647	10,329	8,318	......	......	......	14,776	5	......	5	5,472	11,174	6,750	4,424	9.219	9.092	127	......
1911	18,311	10,831	7.480	......	......	......	14,079	168	......	168	5.477	21,585	12,300	9,285	5,559	4,050	1,509	......
1912	19.546	10,816	8,730	......	......	......	12,446	2,681	......	2,681	5,094	25.949	12,800	13,149	5,591	2.430	3,161	......
1913	18,605	9,003	9,602	......	......	......	9,981	5,275	720	4,555	4,497	33,040	12,750	20,290	5.985	2,220	3,765	......
1914	15,926	7,606	8.320	......	......	......	7,031	4,831	925	3,906	3.821	37,479	13,300	24,179	12,547	3,740	3,807	......
1915	13,548	6,468	7,080	......	......	......	8,035	4.319	783	3,536	3,553	33,311	11,150	22,161	6,007	1,500	4,507	......
1916	14,381	5,971	8,410	......	......	......	8,403	4,852	1,235	3,617	3.231	32.157	11,300	20,857	6,769	1,735	5,034	......
1917	15,939	5,664	10,275	......	......	......	8,496	6,295	3,260	3,035	3.253	29,488	10,580	18,908	7,072	1,807	5,265	......
1918	16,283	5,392	10,891	......	......	......	7,922	5,420	2,965	2,455	3,051	27.440	10,240	17,200	6,609	1,866	4,743	......
1919	16,386	5.306	11,080	281	......	281	7.563	4.555	2,685	1,870	2,811	26,133	9.670	16,463	5,590	1,893	3,697	......
1920	15,464	5,224	10,240	7,276	......	7,276	7,456	4,140	2.520	1,620	2,607	25.217	7,480	17,737	5,424	1,940	3,484	......
1921	12,341	4,131	8,210	18,085	2,288	15,797	6,716	3,261	1,980	1,281	2,056	24,172	*6,500	*17,672	4,614	*2,000	*2,614	......
1922	9,159	4,077	5.082	11,891	2,625	9,266	7,317	2,815	1,710	1,105	2,417	24,152	*6,000	*18,152	5,543	*2,050	*3,493	......
6 mo. 1923	2,443	1,847	596	4,073	1,067	3,006	3,697	1,169	710	459	1,087	11,597	*3,000	*8,597	2,540	*1,050	*1.490	39
Total	268,949	113,163	155,786	41,606	5,980	35,626	239,317	49,786	19,493	30,293	66,144	365,779	136,705	229,074	95,077	43,381	51,696	39
Future	318,600	......	......	116,140	......	......	175,996	13,939	......	......	33,992	......	......	498,000		......	......	10,905
Ultimate	587,549	......	......	157,746	......	......	415,313	63,725	......	......	100,136	......	......	958,856		......	......	10,944

* Estimated. † All under 20° Baumé. ‡ Practically all under 20° Baumé. § All over 20° Baumé.

TABLE VI

COASTAL PETROLEUM PRODUCTION

(in Thousands of Barrels)

Year	Santa Barbara County				Ventura County							Miscellaneous (Includes) Arroyo Grande, Sargent, Moody Gulch, Half Moon Bay		
	Summerland	Casmalia–Cat Canyon Lompoc–Santa Maria			Ventura–Newhall Bardsdale, Conejo, Ojai, Piru, Santa Paula, Simi, Sespe, Newhall			South Mountain			Ventura Ave.			
	−20°†	Total	−20°	+20°	Total	−20°	+20°	Total	−20°	+20°	+20°‡	Total	−20°	+20°
Prior	...	...	...	...	175	...	175	...	...	...	...	...	...	...
1876–93	...	...	...	...	4,595	...	4,595	...	...	...	...	...	...	...
1894	2	...	...	...	570	...	570	...	...	...	...	15	15	...
1895	17	...	...	...	475	...	475	...	...	...	...	4	4	...
1896	40	...	...	...	299	...	299	...	...	...	...	2	1	1
1897	130	...	...	...	631	...	631	...	...	...	...	4	4	...
1898	132	...	...	...	764	...	764	...	...	...	...	3	3	...
1899	208	...	...	...	744	...	744	...	...	...	...	2	2	...
1900	183	...	...	...	629	...	629	...	...	...	...	249	249	...
1901	204	...	...	...	496	...	496	...	...	...	...	...	...	...
1902	136	94	...	94	646	...	646	...	...	...	...	...	...	...
1903	131	205	...	205	682	...	682	...	...	...	...	4	2	2
1904	121	700	...	700	651	...	651	...	...	...	...	39	34	5
1905	97	3,403	...	3,403	477	...	477	...	...	...	...	30	28	2
1906	73	4,799	46	4,753	404	...	404	...	...	...	...	10	10	...
1907	69	8,249	90	8,159	436	...	436	...	...	...	...	69	69	...
1908	68	8,699	269	8,430	498	...	498	...	...	...	...	125	125	...
1909	66	8,017	471	7,546	517	...	517	...	...	...	...	127	127	...
1910	75	7,608	1,350	6,258	653	16	637	...	...	...	...	59	59	...
1911	71	7,465	1,620	5,845	662	17	645	...	...	...	...	61	61	...
1912	66	6,802	730	6,072	860	18	842	...	...	...	...	46	46	...
1913	62	5,818	635	5,183	1,022	9	1,013	...	...	...	...	27	27	...
1914	56	4,303	487	3,816	968	10	958	...	...	...	...	27	27	...
1915	53	4,537	690	3,847	1,036	9	1,027	...	...	...	...	27	27	...
1916	57	4,422	810	3,612	1,119	9	1,110	3	3	...	...	27	27	...
1917	57	5,798	2,460	3,338	1,125	10	1,115	60	60	...	1	27	27	...
1918	55	7,144	3,450	3,694	979	10	969	359	359	...	49	27	27	...
1919	54	6,031	3,205	2,826	1,052	...	1,052	683	683	...	57	27	27	...
1920	55	5,928	2,755	3,173	1,020	...	1,020	992	992	...	110	26	26	...
1921	54	5,563	2,200*	3,363*	988	...	988	1,185	1,185	...	202	24	23	1
1922	48	3,798	1,900*	1,898*	854	...	854	1,443	1,430	13	719	25	24	1
6 mo. 1923	26	1,543	930*	613*	389	...	389	734	726	8	750	21	20	1
Total	2,466	110,926	24,098	86,828	26,416	108	26,308	5,459	5,438	21	1,888	1,134	1,121	13
Future	198	57,247	...	...	7,162	...	...	6,359	...	...	7,920	1,200	...	...
Ultimate	2,664	168,173	...	...	33,578	...	...	11,818	...	...	9,808	2,334	...	...

* Estimated. † All under 20° Baumé. ‡ All over 20° Baumé.

TABLE VII

TABLE VII

Los Angeles Basin Petroleum Production

(in Thousands of Barrels)

Year	Los Angeles County: Los Angeles, Salt Lake, Beverly Hills −20°†	Long Beach +20°‡	Montebello Total	Montebello −20°	Montebello +20°	Santa Fe Springs −20°§	Torrance Redondo Total	Torrance Redondo −20°	Torrance Redondo +20°	Whittier Total	Whittier −20°	Whittier +20°
1876–93												
1894	196											
1895	750											
1896	903											
1897	1,064											
1898	1,126											
1899	1,052											
1900	1,280											
1901	1,830											
1902	2,027											
1903	794											
1904	1,241											
1905	2,227											
1906	2,676											
1907	3,372											
1908	5,139											
1909	4,351											
1910	3,730											
1911	3,224											
1912	3,073									747	450*	297*
1913	2,899									690	450*	240*
1914	2,504									637	400*	237*
1915	2,110									758	450*	308*
1916	1,721									1,015	500*	515*
1917	1,502		790	0	790					1,157	462	695
1918	1,398		6,839	451	6,388					1,046	438	608
1919	1,341		12,101	1,604	10,497					1,001	373	628
1920	1,311		11,125	2,825	8,300					842	369	473
1921	1,345	76	9,066	2,878	6,188	208				735	411	324
1922	1,258	18,561	6,692	2,492	4,199	11,033	191	47	144	718	372	346
5 mo. 1923	599	26,907	2,136	1,101	1,035	31,153	605	151	454	327	192	135
Total	58,043	45,544	48,749	11,351	37,398	42,394	796	198	598	9,673	4,867	4,806
Future	22,619	84,456	18,867			130,356	31,994			8,379		
Ultimate	80,662	130,000	67,616			172,750	32,790			18,052		

Year	Orange County: Brea-Olinda Fullerton-Puente Total	Brea-Olinda Fullerton-Puente −20°	Brea-Olinda Fullerton-Puente +20°	Coyote Hills Total	Coyote Hills −20°	Coyote Hills +20°	Huntington Beach Total	Huntington Beach −20°	Huntington Beach +20°	Richfield Total	Richfield −20°	Richfield +20°
1876–93												
1894												
1895												
1896												
1897	12	12*										
1898	60	60*										
1899	218	218*										
1900	512	350*	162*									
1901	753	450*	303*									
1902	1,104	500*	604*									
1903	2,306	780*	1,526*									
1904	2,225	850*	1,375*									
1905	2,118	880*	1,238*									
1906	2,435	1,120*	1,315*									
1907	3,294	1,650*	1,644*									
1908	3,273	2,300*	1,973*									
1909	5,157	3,000*	2,157*									
1910	6,281	3,910	2,371									
1911	7,081	3,860	3,221									
1912	5,813	3,020*	2,793*	1,359	85*	1,274*						
1913	6,190	3,165*	3,025*	3,777	270*	3,507*						
1914	6,495	3,240*	3,255*	6,999	525*	6,474*						
1915	5,662	2,750*	2,912*	6,611	610*	6,001*						
1916	5,076	2,412	2,664	8,589	878	7,711						
1917	4,751	3,157	1,594	11,458	1,291	10,167						
1918	4,403	2,506	1,897	12,615	492	12,123						
1919	4,350	2,567	1,783	10,240	561	9,679				965	13	952
1920	5,391	2,678	2,713	8,732	1,362	7,370	38		38	2,565	365	2,200
1921	6,013	2,416	3,597	7,419	1,356	6,063	2,519	263	2,256	8,207	1,007	7,200
1922	4,513	1,454	3,059	7,000	1,045	5,955	11,169	1,227	9,942	8,315	847	7,468
5 mo. 1923	2,027	660	1,367	2,030	364	1,666	18,286	432	17,854	3,247	618	2,629
Total	98,513	49,965	48,548	86,829	8,839	77,990	32,012	1,922	30,090	23,299	2,850	20,499
Future	72,487			9,556			111,496			62,296		
Ultimate	171,000			96,485			143,508			85,595		

* Estimated. † Practically all under 20° Baumé. ‡ Practically all over 20° Baumé. § All over 20° Baumé.

TABLE VIII

PETROLEUM PRODUCTION ABOVE AND BELOW 20° BAUMÉ

(In Thousands of Barrels)

San Joaquin Valley				Coastal				Los Angeles Basin			
Year	Total	−20°	+20°	Year	Total	−20°	+20°	Year	Total	−20°	+20°
1896	14	....	14	1876–1896 inc.	6,194	79	6,115	1894, 95, 96	1,849	1,849	....
97	70	....	70	97	765	134	631	97	1,076	1,076	....
98	164	10	154	98	899	135	764	98	1,186	1,186	....
99	454	15	439	99	954	210	744	99	1,270	1,270	....
1900	1,467	919	548	1900	1,061	432	629	1900	1,792	1,630	162
01	4,428	3,927	501	01	700	204	496	01	2,583	2,280	303
02	10,349	9,828	521	02	876	94	782	02	3,131	2,527	604
03	20,213	18,363	1,850	03	1,022	133	889	03	3,100	1,574	1,526
04	24,571	20,936	3,635	04	1,511	155	1,356	04	3,466	2,091	1,375
05	25,947	19,197	6,750	05	4,007	115	3,892	05	4,345	3,107	1,238
06	22,227	15,837	6,390	06	5,286	129	5,157	06	5,111	3,796	1,315
07	24,613	18,433	6,180	07	8,823	228	8,595	07	6,666	5,022	1,644
08	29,505	22,860	6,645	08	9,390	462	8,928	08	9,412	7,439	1,973
09	39,956	32,181	7,775	09	8,727	517	8,210	09	9,508	7,351	2,157
1910	59,293	46,419	12,874	1910	8,395	1,500	6,895	1910	10,011	7,640	2,371
11	65,179	46,797	18,382	11	8,259	1,769	6,490	11	10,305	7,084	3,221
12	71,307	43,586	27,721	12	7,776	860	6,915	12	10,992	6,628	4,364
13	77,383	39,171	38,212	13	6,929	733	6,196	13	13,556	6,784	6,772
14	81,635	36,423	45,212	14	5,354	580	4,774	14	16,635	6,669	9,966
15	68,773	31,489	37,284	15	5,653	779	4,874	15	15,141	5,920	9,221
16	69,793	31,875	37,918	16	5,628	906	4,722	16	16,401	5,511	10,890
17	70,543	33,060	37,483	17	7,068	2,614	4,454	17	19,658	6,412	13,246
18	66,725	31,436	35,289	18	8,613	3,901	4,712	18	26,301	5,285	21,016
19	63,319	29,928	33,391	19	7,904	3,969	3,935	19	29,998	6,459	23,539
1920	67,584	27,227	40,357	1920	8,131	3,828	4,303	1920	30,004	8,910	21,094
21	71,245	25,671	45,574	21	8,016	3,462	4,554	21	35,588	9,676	25,912
22	63,294	26,196	37,098	22	6,887	3,402	3,485	22	69,450	8,743	60,707
6 mo. 1923	26,645	12,458	14,187	6 mo. 1923	3,463	2,452	1,011	6 mo. 1923	87,317	4,117	83,200
Total	1,126,696	624,242	502,454	Total	148,290	33,782	114,508	Total	445,852	138,036	307,816
Future	1,167,623	....	....	Future	80,085	....	....	Future	552,606	....	....
Ultimate	2,294,319	....	....	Ultimate	228,375	....	....	Ultimate	998,458	....	....

TABLE IX

CALIFORNIA PRODUCTION
(In Thousands of Barrels)

Year	Totals		
	Total	−20°	+20°
Prior	175	....	175
1876–93	4,595	....	4,595
1894	783	213	570
1895	1,245	770	475
1896	1,258	944	314
1897	1,911	1,210	701
1898	2,249	1,331	918
1899	2,678	1,495	1,183
1900	4,320	2,969	1,351
1901	7,710	6,411	1,299
1902	14,357	12,489	1,868
1903	24,334	20,007	4,327
1904	29,549	23,181	6,368
1905	34,298	22,429	11,869
1906	32,623	19,762	12,861
1907	40,102	23,683	16,419
1908	48,307	30,759	17,548
1909	58,192	40,196	17,996
1910	77,698	55,559	22,139
1911	83,744	55,591	28,153
1912	90,073	51,075	38,998
1913	97,867	46,687	51,180
1914	103,624	43,672	59,952
1915	89,567	38,188	51,379
1916	91,822	38,292	53,530
1917	97,268	42,085	55,183
1918	101,638	40,621	61,017
1919	101,222	40,357	60,865
1920	105,721	39,967	65,754
1921	114,850	38,810	76,040
1922	139,633	38,343	101,290
6 mo. 1923	117,425	18,277	99,148
Total	1,720,838	795,373	925,465
Future	1,800,314	....	....
Ultimate	3,521,152	....	....

OIL RESERVES

Data on oil reserves are valuable as an item in the inventory of a nation's or state's natural wealth; and to industry, for example, in making broad forecasts of the trend of fuel and power development and probable future economic relationship of petroleum or its products to its natural fuel and power competitors. The data are also useful for comparing the economic importance of one oil-

producing district with another. The constructive uses of such estimates are limited.

One of the commonest uses to which estimates of oil reserves are put is in predicting how long the supply will last. When the petroleum economist reports that there is a forty-five days' supply of gasoline in storage, he means that at the going rate of consumption the supply would last 45 days. Similarly for petroleum, when the geologist reports, let us say, 1,600,000,000 barrels of oil still recoverable in California, there is also a tendency to interpret this supply as though it were a product stored above ground, and, should the annual rate of consumption be 200,000,000 barrels, the supply would be sufficient to last eight years! Naturally such an interpretation requires a number of qualifying remarks, but it is usually placed before the lay public thus: "California's Petroleum Reserves Practically Exhausted, Remaining Supply only Sufficient for Eight Years." Such interpretations do the petroleum industry more harm than good. Supposing the demand for the next eight years were equal to the present computed reserve, it would be a physical impossibility to recover the oil to the last barrel within that time.

It is conceivable that with a resource such as coal, an accurate estimate of reserve tonnage could be made, and further, that if the demand were sufficiently urgent all of the reserve, to the last ton, could be mined in a fixed term of years. In oil fields, however, nature rather than man has formulated the methods of extraction, or perhaps set her limitations upon the processes of expulsion; and, regardless of the urge, man must, to a certain extent, bide bis time and let natural laws work and oil wells decline in their own way.

An estimate of oil reserves can be advantageously used in comparing past performances of various fields with future expectations. It shows the shifts in economic predominance from one field or district to another over a long period and gives an idea of the future trend. In a state such as California where so much oil is used for fuel and yet the refined products, as gasoline and lubricants, are so important, comparisons of estimates of the quantities recoverable from various oil fields weighted by the quality of crude produced therein, give the producer, refiner, and marketer, some idea of the type of product that will be available ten or fifteen years hence.

A number of estimates have been made at one time and another of the recoverable oil content of California oil fields. Some of the estimates were for proved oil land only, others were for both proved and possible oil land. In one or two instances the inclusion of possible oil land gives such free range to the imagination that the quantities become imponderable and we are engulfed in a fathomless and valueless sea of hypothetical petroleum. Where estimates vary so widely one naturally wonders which will prove to have been closest to the mark when the final statistics of California oil production are recorded. The tendency has been toward conservatism, that is, revision downward. Some estimators in revising their data from time to time maintain practically the same amount for total ultimate recovery and revise the acreage and barrelage factors. Thus a mass of variables and inconsistencies are kept within a convincing exterior, leaving the final determination of the accuracy of details to a post-mortem examination by statisticians of the future.

It is evident that estimates of future recovery are subject to continuous modification, requiring revision upward, due to: (1) Development of new fields; (2) improved methods of production; (3) more general prevention of waste of gas—hence conservation of expulsive forces; (4) changes in physical condition of wells; (5) possible deeper zones in present producing fields; (6) improved drilling methods making possible deeper zones available; (7) increases in proved acreage of developed fields, and requiring revision downward, due to: (1) Unexpected encroachment of edge-water; (2) more rapid decline of expulsive forces than apparent from records of flush production; (3) influence of infiltrating water, through failures in water shut-offs or lack of care in drilling, or unexpected appearance in holes where it had been held in check by high pressures of flush production.

The estimates of ultimate recoverable oil in the various oil fields of California made by a committee from the Pacific Coast membership of the American Association of Petroleum Geologists as of July 1, 1921, in co-operation with and for the United States Geological Survey, were based on recovery per acre of proved oil land. The estimated future recovery from 101,935 acres of proved oil

land as of July 1, 1921, was set at 1,680,000,000 barrels with an ultimate recovery of 3,095,000,000 barrels, or 30,400 barrels per acre. The writers have attempted to bring these estimates down to July 1, 1923, making such modifications and revisions as the results of recent development seem to require.

The results of development within the two-year period following July 1, 1921, show of how little value the estimates of possible oil land would be when compared with actual results. There is little in California experience prior to July, 1921, upon which, for example, estimates of possible acreage or recovery for the three big fields of the Los Angeles basin could be predicated.

Petroleum geologists and engineers of California seem to be quite unanimous in the opinion that possible oil lands, that is, geologically favorable but as yet undeveloped areas, should not be included in an estimate of reserves. However, there seems to remain an unsatisfied desire to know what would be the total quantity of recoverable oil if the location and capacity of every field within the state, both developed and undeveloped, were known and could be accurately computed. The writers suggest that if the total possible acreage, as geologically determined, were multiplied by the average estimated ultimate recovery per acre for all proved areas, that this barrelage for possible oil land, added to the barrelage of recovery for proved oil land, could be advanced as the *maximum* estimate of ultimate recoverable oil and the minimum estimate may safely be taken as that of the estimated total ultimate for present proved acreages.

For example, the committee's estimate of possible oil land in California as of July 1, 1921, was 42,200 acres. This estimate was made by Vander Leck[1] from data prepared for his bulletin on the oil resources of California. The estimated ultimate recovery per acre for 101,935 acres of proved oil land of the state was 30,400 barrels. Applied to possible oil land this would give an ultimate production of 1,282,880,000 barrels. Therefore, as suggested above, the maximum estimate of ultimate recovery in the state would have been 4,377,880,000 barrels as of July 1, 1921. The probabilities for

[1] Lawrence Vander Leck, "Petroleum Resources of California," *Cal. State Mining Bureau, Bull. 89*, 1921.

error in this maximum estimate are great, however, because of the uncertainty of the acreage factor.

Before giving the few explanatory details of the revisions of the committee's estimate of July 1, 1921, it is interesting to compare the above maximum estimate of four and a third billions with some previous estimates.

Estimates Prior to July 1, 1921.—In 1908, an estimate of the petroleum reserves of the United States was made by the United States Geological Survey, under the direction of David T. Day and published in *Bulletin 394*.

As regards California the report says: "In Canifornia very careful measurements by Mr. Arnold have resulted in an estimate of 8,500,000,000 barrels of petroleum stored in the rocks of that state, of which 5,000,000,000 may be expected to be produced."

No analysis is given of the field details for California. However, it seems that possibly half of the minimum quantity may have been expected from the Coalinga oil field, for in *U.S.G.S. Bulletin 398*, published in 1910, Arnold gave an estimated recoverable content for Coalinga of 2,000,000,000 barrels for the west side field and 800,000,000 barrels for the east side—a total of 2,800,000,000 barrels. Most recent estimates for Coalinga show an ultimate recovery of about 600,000,000 barrels or less than one-fourth of the estimate of 1908. Possibly the original high estimate was based upon the records of flush productions. At any rate the comparison illustrates, as will some other estimates which follow, the trend toward conservatism in preparing data of oil reserves.

In June, 1912, an estimate of petroleum reserves of California was published in a paper reprinted from *Transactions of the Commonwealth Club of San Francisco*. A survey of the Fuel Resources of California was made by a committee of which M. L. Requa was chairman. According to the report the data of oil reserves were prepared by Arthur F. L. Bell. The total estimated extractable oil content for 99,200 acres, classed as proved, is given as 4,255,000,000 barrels. In addition, Bell prepared an estimate of possible acreage and estimated the production derivable therefrom. The total possible acreage is given as 338,320 acres and the ultimate production as 13,258,000,000 barrels.

As regards acreage the report says: "It will be noted that Mr. Bell gives a total of possible and proved of 437,520, as compared with an estimate of 360,000 by M. L. Requa, and the estimate of the United States Geological Survey of 544,000."

In a discussion of The Petroleum Resources of the United States as of January 1, 1915, Arnold[1] gave an estimated ultimate recoverable content for the oil fields of California as 3,041,274,000 barrels and a future recovery of 2,300,000,000 barrels. Arnold fixed the proved area of 99,840 acres and an additional "prospective" area of 25,600 acres for which no barrelage was given. The estimated average ultimate recovery per acre is 30,000 barrels.

Senate Document No. 310, of February 3, 1916, gives an estimate of California petroleum remaining underground as of January 1, 1916, made by the United States Geological Survey and the United States Bureau of Mines. The amount is 2,345,000,000 barrels. The production of petroleum in California up to January 1, 1916, was 878,367,000 barrels making an estimated ultimate recovery of 3,223,367,000 barrels.

Beal[1] in his bulletin on decline and ultimate production of oil wells made an estimate as of December 31, 1917 of 3,300,000,000 barrels as the ultimate production for California oil fields. This was on a basis of 1,000,000,000 barrels produced to January 1, 1918, and an estimated future recovery of 2,300,000,000 barrels.

In a paper presented at the annual meeting of the Society of Automotive Engineers, in February, 1919, David White estimated the available oil left in the ground in California, as of January 1, 1919, as 2,250,000,000 barrels. This, added to a recovery up to the end of 1918 of 1,114,000,000 barrels, gave an estimated ultimate production of 3,364,000,000 barrels.

The estimate made by the California Committee of the American Association of Petroleum Geologists, as of July 1, 1921, made for the United States Geological Survey, gave a future production of 1,680,000,000 barrels for that date. The estimate as finally pub-

[1] Ralph Arnold, "The Petroleum Resources of the United States," *Economic Geology*, Vol. 9 (December, 1915), No. 8, p. 695.

[2] Carl H. Beal, "Decline and Ultimate Production of Oil Wells," *Bureau Mines Bull. 177* (1919), p. 201.

lished by the United States Geological Survey was 1,850,000,000 barrels as of January 1, 1922, representing an upward revision of about 230,000,000 barrels. California's ultimate recovery based upon the Survey's revision therefore, was 2,314,000,000 barrels.

The above estimates are summarized in Table X.

TABLE X

ESTIMATES OF CALIFORNIA OIL RESERVES MADE UP TO CLOSE OF 1921

Date of Estimate	Authority	Ultimate Production Proved Oil Land (Barrels)	Proved Acreage	Ultimate Production Possible Oil Land (Barrels)	Possible Acreage
1908..........	U. S. G. S., Day-Arnold	5,000,000,000	....	8,500,000,000	....
1912..........	M. L. Requa, A. F. L. Bell	4,255,000,000	99,200	13,258,000,000	338,320
1915..........	Ralph Arnold	3,041,274,000	99,840	....	25,600
1916..........	U. S. G. S.-U. S. Bureau of Mines Senate Document 310	3,223,367,000	....	....	....
1917..........	Bureau of Mines, Beal	3,300,000,000	160,745	....	....
1918..........	David White	3,364,000,000	....	....	....
July 1, 1921...	California Committee A. A. P. G.	3,095,000,000	....	....	....
1921..........	U. S. G. S.	3,314,000,000	....	....	....

The following is a tabulation of the estimates of future and ultimate productions of proved oil land in California as prepared by the California Committee of the American Association of Petroleum Geologists.

TABLE XI

ESTIMATES OF CALIFORNIA OIL RESERVES MADE BY COMMITTEE OF AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS AS OF JULY 1, 1921

Field	Past Production to July 1, 1921	Future Production	Ultimate Production	Proved Acres	Ultimate per Acre
Kern River..............	225,409,170	189,753,095	415,162,265	7,300	57,000
McKittrick..............	61,805,818	38,368,658	100,174,476	1,230	81,500
Midway Sunset...........	411,254,000	555,000,000	966,254,000	42,037	23,000
Coalinga................	252,290,828	335,383,000	587,673,828	15.900	37,000
Santa Maria, Lompoc, Summerland	104,006,209	65,294,000	169,300,209	9,173	18,500
Newhall, Ventura Co.	27,500,000	25,543,000	53,043,000	3,215	16,500
Los Angeles, Salt Lake	55,500,000	25,000,000	80,500,000	2,700	29,500
Whittier Fullerton........	212,700,000	242,932,000	455,632,000	6,400	71,000
Lost Hills Belridge........	44,500,000	19,200,000	63,700,000	4,500	14,000
Huntington Beach, Signal Hill	800,000	42,625,000	43,425,000	1,475	29,500
Elk Hills................	17,825,000	139,901,000	157,726,000	7,385	21,000
Misc. Sargent, Arroyo Grande, etc.	1,500,000	1,250,000	2,750,000	620	4,400
	1,415,091,025 (1,415,000,000)	1,680,249,753 (1,680,000,000)	3,095,340,778 (3,095,000,000)	101,935	30,400

The above estimate has been brought down to July 1, 1923, by the authors. Revisions in proved acreages are necessary for Huntington Beach, Long Beach, Santa Fe Springs, Torrance, and Wheeler Ridge. The three latter fields were not included in the original estimate. The first two fields were included, although in the initial stages of development and underestimated. The status of other areas has not changed greatly since July 1, 1921. The estimates of ultimate production for Huntington Beach and Long Beach were revised upward as follows: Long Beach from 5,000,000 to 130,000,000 barrels and Huntington Beach from 38,425,000 to 143,508,000 barrels. The estimates for the three latter fields have been determined as follows: Santa Fe Springs, 172,750,000 barrels; Torrance, 32,790,000 barrels, and Wheeler Ridge 10,944,000 barrels. The estimates for Huntington Beach, Long Beach, and Santa Fe Springs are the average of a number of estimates of ultimate recovery per acre furnished the writers by several engineers. They are considered conservative, but data of production after the fields have passed from the flowing stage may show them to be too high.

The net addition of ultimate recoverable oil to the estimate of July 1, 1921, is, as of July 1, 1923, 448,567,000 barrels—making a total ultimate recovery, since the development of the four new fields of the Los Angeles basin and Wheeler Ridge in Kern County, of 3,543,567,000 barrels.

The total proved area set by the committee as of July 1, 1921, was 101,935 acres. To this has been added proved acreages as determined by the State Oil and Gas Supervisor as of July 1, 1923, for Santa Fe Springs, Torrance, and Wheeler Ridge with adjustments also for Long Beach and Huntington Beach. This gives a revised total proved acreage of 106,843. The average ultimate recovery per acre is now 33,100 barrels per proved acre as compared with 30,400 barrels, the estimate prior to revision. The details of revised estimates are shown in the totals in Tables V, VI, VII, VIII, and IX.

The totals of the original and revised estimates are as follows:

TABLE XII

Date of Estimate	Past Production	Future Production	Ultimate Production	Proved Acres	Ultimate per Acre
July 1, 1921..............	1,415,000,000	1,680,000,000	3,095,000,000	101,935	30,400
July 1, 1923..............	1,721,000,000	1,823,000,000	3,544,000,000	106,843	33,100

Proved and developed acreages.—In the above estimates the proved acreage is about 7,000 acres lower than the total proved acreage for the state as determined by the Department of Petroleum and Gas of the State Mining Bureau. This is due principally to lower estimates for Midway-Sunset, Coalinga, and Elk Hills oil fields. It is possible that these estimates approach more nearly the developed acreage within proved areas than the total proved acreages as determined by the Department of Petroleum and Gas. The following analysis shows that there is a distinction.

The total proved acreage for all oil fields of the state on July 1, 1923, as determined by the Department of Petroleum and Gas of the State Mining Bureau, was 113,449 acres. Of this amount 83,885 acres is in the Valley fields of Fresno and Kern County, 14,011 acres in the Coastal fields, and 15,553 acres in the Los Angeles basin. Up to July 1, 1923, 14,242 wells had been drilled within the proved areas and, weighted by the average acreage per well peculiar to each field[1], had developed 58,808 acres leaving 54,641 classed as undeveloped.

Table XIII shows the data of proved areas, acreage per well, developed and undeveloped acreages for individual fields as of July 1, 1923, and range of Baumé gravity of crude oil.

Conclusion.—It is apparent that the method of determining a number of factôrs such as proved and developed acreages, spacing of wells, rate of drillings of new wells, and abandonment of depleted wells, will cause slight variations in estimates. To illustrate this point the authors made an estimate of future recovery for California oil fields of as January 1, 1922, using a composite decline curve for all California oil fields, excepting the recently developed fields

[1] R. E. Collom, "Notes on California Oil Field Practice," *Bull. A. A. P. G.*, Vol. 7, No. 2 (Mar.-Apr., 1923), pp. 114, 116.

TABLE XIII

PROVED AND DEVELOPED ACREAGES AND AVERAGE ACREAGE PER WELL, CALIFORNIA OIL FIELDS

County	Oil Fields	Present Range in Gravity Degrees Baumé	Proved Acreages July 1, 1923	Number of Wells Drilled within Proved Areas July 1, 1923	Average Acreage per Well Bases Average Spacing of Wells	Total Developed Acreage on Basis Average Allotted Acreage per Well July 1, 1923	Undeveloped Acreage within Proved Areas
Fresno	Coalinga	12–37	14,654	1,736	6.1	10,589	4,065
Kern	Belridge	11–35	2,175	266	5.4	1,436	739
	Devils Den	14–15	30	26	.5	13	17
	Elk Hills	15–45	9,080	229	8.0	1,832	7,248
	Kern River	11–15	7,154	2,558	2.4	6,139	1,015
	Lost Hills	12–37	2,250	391	4.2	1,642	608
	McKittrick	11–18	1,565	426	2.0	852	713
	Midway	12–32	40,808	2,876	6.2	17,831	22,977
	Sunset	9–27	5,809	824	3.4	2,811	2,998
	Wheeler Ridge	25	360	2	4.5	9	351
Total Valley Fields	....	....	83,885	9,404	....	43,154	40,731
Los Angeles	Beverly Hills	12–19	110	22	5.0	110	0
	Long Beach	17–31	1,000	317	1.4†	444	556
	Montebello	11–29	1,127	190	4.5	855	272
	Newhall	14–40	210	137	1.5*	210	0
	Salt Lake	11–22	934	322	2.5	805	129
	Santa Fe Springs	28–36	1,995	230	2.5*	575	1,420
	Torrance	14–28	1,093	35	4.7	165	928
	Whittier	14–30	627	258	2.2	568	59
Orange	Brea Olinda	12–32	1,969	583	1.7	991	978
	Coyote Hills	12–25	2,722	295	5.2	1,534	1,188
	Huntington Beach	13–30	2,476	381	2.4‡	914	1,562
	Richfield	13–26	1,290	243	4.4	1,069	221
Total Los Angeles Basin	....	....	15,553	3,013	....	8,240	7,313
Santa Barbara	Casmalia	8–14	1,900	114	4.8	547	1,353
	Cat Canyon	10–18	1,550	79	6.7	529	1,021
	Lompoc	14–24	1,193	37	19.4	718	475
	Santa Maria	10–32	4,660	289	10.5	3,034	1,626
	Summerland	14–15	120	387	.3*	120	0
Santa Clara	Sargent	16	80	8	4.4	35	45
San Luis Obispo	Arroyo Grande	13–16	600	34	3.3	112	488
Ventura	Bardsdale	18–32	560	180	1.4	252	308
	Conejo	14–16	40	111	0.4−	40	0
	Ojai	11–36	420	90	2.8	252	168
	Piru	14–28	517	159	2.3	366	151
	Santa Paula	20–35	430	143	2.0	286	144
	Simi	18–39	596	70	5.8	406	190
	Sespe	19–33	450	89	3.4	303	147
	South Mountain	18–31	630	54	3.7	200	430
	Ventura	20–50	265	51	4.2	214	51
Total Coastal Fields	....	....	14,011	1,895	....	7,414	6,597
Grand total	....	....	113,449	14,242	4.1§	58,808	54,641

* Partly town lots—some locations as close as 3 wells per acre (not including 80 acres of closely drilled town lots raises acreage per well to 2.8).

† Partly town lots—some off-set locations only 50 feet apart.

‡ About ⅓ town lots—many locations less than 100 feet apart.

§ Average acreage for California.

of the Los Angeles basin, which are a departure from previous California experience. A program of drilling and abandonment conformable with past performance was used and production decline carried out to a minimum of 1,000 barrels per well per year. The result gives a future recovery from January 1, 1922, of 1,603,540,000 barrels not including, as stated, certain new fields. This is 18,000,000 barrels, or 1 per cent, less than the committees' estimate with Long Beach and Huntington Beach excluded.

A comparison of the various estimates of ultimate recovery, made since 1915, show a variation of 1 to 3 per cent for proved areas not including the gusher fields of the Los Angeles basin. These fields have upset all previous calculations and apparently justify the addition of 450,000,000 barrels to California's ultimate production from the present proved oil fields.

DISCUSSION

Ralph Arnold: I think the production of the last few months should not be too seriously considered as bearing on future conditions. About sixteen years ago, after I had finished an examination of the oil fields of California for the government, I made a little estimate as regards the territory in California that would probably not produce oil. I said little as to the future possibilities of oil, and I am glad I did not at that time. I based my conclusion on the theory that the oil in California comes from diatoms, and with that theory in mind, I studied the formations found throughout the state and reached the conclusion that the territory southeast of the Santa Ana River and north of Coalinga would never yield any large producing fields. That conclusion was reached sixteen years ago. There have been millions of dollars spent north of Coalinga and southeast of Santa Ana River, but no producing field has yet been found in either district.

The territory within the boundaries mentioned is large, but it is not limitless as regards structures. I have yet to see a place in California where there is structure not having some reflection of this structure at the surface. There are no fields with the possible exception of the Salt Lake Field, west of Los Angeles, without some topographical reflection of the structure at the surface. And even in this case, there are brea deposits on the faulted anticline which gave the clue to start development in that field. A test of the various structures within the two limits mentioned would be a pretty good test of the possibilities of California. As these structures are now largely tested I look for few, if any, more large fields in this State.

S. H. Gester: I think we are going to find several new fields, but the production will probably come at such distant time that it will not have any such

general effect as there has been caused in the last six months. Any new production will be spread over a number of years. The fields that have been recently discovered in the last three or four months by single wells, namely, the Compton, Torrance, and Wheeler Ridge fields are not going to be particularly large producers. They will not be anything like Santa Fe Springs.

ALEXANDER DEUSSEN: I would like to be enlightened on one point. Would it be economically possible to lift this oil 5,000 feet by pumping?

IRVING V. AUGUR: I think there is a popular fallacy in the idea that when a well goes off production at 5,000 feet, it is necessary to pump it from that depth. That is not correct. When a well stops flowing at 5,000 feet, the fluid level is usually at a depth of about 1,000 or 1,500 feet, and it will take a number of years to lower the fluid level down to 5,000 feet.

JOSEPH JENSEN: You do not need to worry about pumping the deep wells as they are doing it in the West Coyote field already where they are lifting oil 4,000 feet by using two pumps. We have had trouble in wells on account of too much gas interfering with the wells, but the oil-well supply companies will solve the question. Engineers have come from the mid-Continent fields where they have problems of pumping from 3,000 feet. Production will be smaller and the cost of lifting is going to compel us to resort to other measures.

J. ELMER THOMAS: Some of us from the East have been gratified and very much relieved that this surplus of oil flooding the eastern seaports will be eased off in six to nine months. On the other hand, it is reported in the East that the larger refining companies have contracted for millions of barrels of California crude for a period of over five years. If, in accordance with Mr. Jensen's chart, your California local consumption catches up by July of next year (1924), where are they going to get the millions of barrels of oil?

W. W. ORCUTT: They will take it out of storage. There are about 85,000,000 barrels of oil in storage now. No company has sold the oil unless it had the oil in sight. Contracts call for a period of delivery of about a year. I do not know of any contract extending over a period of five years. The contracts of sale that have been made will be filled by the selling companies either from the oil they have in storage or else from present production.

MAX BALL: When will California cease shipping oil to the Eastern markets?

ROBERT B. MORAN: In regard to this forecasting of future production I think most of us realize that the conclusion based on a study of curves of future production is somewhat of a guess. It do not remember exactly the year, but during the war, a statistical report was gotten up showing the petroleum reserves of California in connection with an estimate of reserves for the United States. The report had hardly gone to press before production had started in the three fields of Southern California. I think that Huntington Beach was considered in this account but neither Santa Fe Springs nor Signal Hill had been brought in.

I personally feel that there are going to be additional fields discovered in the Los Angeles Coastal plain. Many of these wells have been started as a

result of a study of the wells already or being drilled, after consideration of some of the geological problems; others are being drilled where it is easy to get acreage. From this drilling, I look to see some additional fields discovered. We had one discovery within the last few weeks at Compton. We do not yet know the extent of this new field, but in any estimation of future reserves of California, I am sure that our figures are going to be upset by a new field such as Compton because it takes considerable time for its development.

MAX W. BALL: Is not the Compton field in large holdings?

ROBERT B. MORAN: It is in town lots cut up into many small tracts—three, four, and five acres and these cannot be kept from being split up. A good many will be divided. A great deal of acreage is in the hands of speculators and smaller concerns who probably are going to let somebody else prove it up. The acreage is undoubtedly split up, but we have no repetition of typical town-lot conditions.

MAX BALL: Torrance is not such a high powered field?

ROBERT B. MORAN: The new development at the southeast end of Torrance is showing up much better than the northwest end of the field. Unfortunately, acreages are very much cut up, and the holdings are in a great many hands. Lots near the last development comprise one acre and half-acre tracts. I am told that within the last few days the wells have come in at about 3,500 barrels, a rate which is considerably higher than hitherto made at Torrance. Many new rigs are going in.

GEOLOGICAL NOTES

NEW GEOLOGICAL MAP OF OKLAHOMA

The United States Geological Survey, in co-operation with the geologists of Oklahoma, is preparing a colored geological map of Oklahoma to be published during the next year. Mr. H. D. Miser is in charge of this work and he has been in Oklahoma about six months compiling data from the geologists, oil companies, and the state Survey. Owing to the very great detail in which the eastern part of the state has been mapped by petroleum geologists, the only additional field work required has been in the Ouachita Mountain region, the Coastal Plain strip south of these mountains, and the Arbuckle-Wichita Mountain area. Compilation in Oklahoma was completed in February. The final map will be the most detailed state geologic map ever published.

The initiation of this project was by the geologists of Oklahoma who felt the need of a detailed areal map. Owing to the insufficiency of funds available for the federal Survey and to the lack of funds for the Oklahoma Geological Survey, it was necessary for the geologists of Oklahoma to defray the cost of field work and of drafting in Oklahoma through the medium of the National Research Council. Funds were raised in amounts varying from $10 to $100 from about 150 geologists and about $2,500 has been secured. Oil companies have furnished information with gratifying liberality and a few have also contributed financially at the request of their respective geologists. Solicitation of companies for funds was purposely avoided in order that the geologists might realize their project without financial assistance. A portion of the money has been used for the employment of draftsmen and the remainder has been given to the National Research Council.

Publication of the colored map must await the preparation of many color-plates engraved in great detail and also very careful printing. In order that the final map may show all available information, a preliminary photolithograph map will be printed and sent to those who have contributed to the project. All geologists are requested to furnish available areal information so that this map may stand the test of time better than any others have done.

Sidney Powers, *Treasurer*

ABSENCE OF METAMORPHOSED SEDIMENTARY ROCKS IN THE TEXAS PANHANDLE

In recently published papers Sidney Powers[1] and Wallace E. Pratt[2] put forward the suggestion that the structures producing gas and oil in the Texas Panhandle were formed by the settling or compacting of the Permian beds over ancient mountains composed of crystalline rocks, while T. S. Harrison[3] favored the theory of igneous intrusions in the form of sills or lacoliths.

In the log of the Amarillo Oil Company's No. 1 Masterson, the first well drilled on the John Ray dome, mention is made of "granite" and "calcamite rock," but no samples of igneous material were obtained from wells drilled in the Panhandle country until January, 1920, when the Ranch Creek Oil Company's No. 1 Masterson encountered, at a depth of about 2,200 feet, the material which has since been referred to as felsite.

Samples of this material were submitted, without comment, to W. Harold Tomlinson, petrographer of Swarthmore, Pennsylvania, who reported as follows: minerals present, orthoclase (80 per cent), quartz, magnetite, muscovite; texture, sparsely porphyritic; structure, dike, probably intrusive; origin, igneous; metamorphism, practically nil; rock species, felsite. Sparse irregular-shaped phenocrysts of orthoclase occur in a base of micro-felsitic material (orthoclase and quartz). Probably intrusive dike. The rock belongs to the rhyolite-granite group and may be classified as either felsite or porphyry.

In a letter accompanying the above report Mr. Tomlinson says: " . . . . I have examined microscopically a section of the sample you submitted and find it to be a dense felsitic rock containing a few irregular phenocrysts of orthoclase. The base is a very fine orthoclase and quartz. Muscovite and magnetite are accessory. The structure is probably an intrusive dike. I would classify it as felsite."

Mr. Tomlinson's statement that the material was probably intrusive caused a close examination to be made of samples from Panhandle wells for evidence of metamorphism in the sedimentary rocks, but we found no such evidence, nor are we aware of any other geologist working in the

[1] Sidney Powers, "Reflected Buried Hills and Their Importance in Petroleum Geology," *Econ. Geol.*, Vol. 17, p. 233, 1922.

[2] Wallace E. Pratt, "Oil and Gas in the Texas Panhandle," *Bull. Amer. Assoc. Pet. Geol.*, Vol. 7, p. 237, 1923.

[3] T. S. Harrison, "Porphyry at Amarillo," *Bull. Amer. Assoc. Pet. Geol.*, Vol. 7, p. 434, 1923.

Panhandle country who has conducted a successful search along these lines.

Several wells on the Bravo, John Ray, and 6,666 domes have drilled into igneous material similar in appearance to that found in the Ranch Creek Oil Company's No. 1 Masterson. This material, no doubt, varies in composition and texture from place to place. It is reasonable to regard this material, in so far as it appears to be intrusive, as having been intruded into the old crystalline rocks prior to the deposition of the gas and oil-producing sedimentaries.

It is our opinion that no well which has been drilled into this felsite or porphyry has passed through it into sedimentary rocks below. An argument involving this statement will first resolve itself into a question concerning the reliability of samples, logs, and other information.

The fact that wells located on or near the tops of the surface structures have encountered igneous rocks at varying depths suggests that the surface of the crystalline mass may be greatly eroded, and that high peaks may rise from the main mass just as they do today in the Wichita Mountains where crystalline rocks are exposed. The point to be stressed is that no metamorphosed sedimentary rocks have yet been found.

DAVID DONOGHUE

HOUSTON, TEXAS
January 15, 1924

CONTRIBUTION TO STRATIGRAPHY OF WESTERN KANSAS[1]

A well known as Whiteside No. 1, drilled in the NW. corner SW. $\frac{1}{4}$ Sec. 2, T. 24 S., R. 23 W., Hodgeman County, Kansas, has contributed some definite information regarding the thickness of certain formations in western Kansas. This well was referred to by the writer in discussing a note by C. T. Lupton, on a geologic section in western Kansas, that appeared in Vol. 6, No. 2, pp. 549–51, of the *Bulletin of the American Association of Petroleum Geologists.* The location was erroneously given as Ford County. At that time cuttings from a depth below 3,655 feet were not available, but two collections—one from 3,640 to 3,650, the other from 3,650 to 3,655—contained fossils that had been determined by P. V. Roundy of the U.S. Geological Survey as "lower Pennsylvanian, but not necessarily basal Pennsylvanian in age." Since that time other cuttings have been studied by Mr. Roundy, who has made the following determinations:

[1] Published by permission of the Director, U.S. Geol. Survey.

3,640–3,650	Imperfect gastropod, probably Pleurotomaria sp.
	Productus spine fragments
	Echinoid spine fragment
	Minute pelecypod, probably a Nucula
	Cytherella n. sp.
	Hollina n. sp.
	Amphissites centronatus var.
	Amphisites n. sp.
3,240	Lingula sp. fragment
3,650–3,665	Fusulinella ? sp.
	Hollina sp.
	Cytherella n. sp.
	Amphissites n. sp.
	Productus spines
3,743	Bairdia 2 species
	Fusulina sp.
	Productus spines
3,750–3,756	Fusulina sp.
	Productus spines
3,822	Ambocoelia sp.
3,810	Bairdia sp.
	Fusulinella sp.
	Fusulina sp.
3,870	Ostracod (new ? genus)
3,905	Fusulina sp. (very abundant)
3,935	Fusulinella sp. (These look as if they were water-worked)
3,980	Polygnathus n. sp.
3,980–3,990	Bairdia of. B. beedei var.
	Fragment Fusulina (certainly not water-worn)
3,993	Fusulina sp.
	Composita ? sp.
4,000	Endothyra sp. (This form, although distinct from the Mississippian E. baileyi, is much closer to it than to the Endothyras found by Mr. Roundy in the Pennsylvanian)
	Composita ? sp.

It will be noted that the evidence of Mississippian age is not conclusive, but there can be no question about the Pennsylvanian age of the strata to a depth of 3,993 feet. As the well was carried to 4,055 feet, and as there was abrupt change in the type of rock at 4,010 feet, it is quite possible that the lower 45 feet are Mississippian or even older rocks.

K. C. HEALD

EXPLORATION FOR OIL IN AUSTRALIA

The Scientific and Technical Committee of the International Petroleum Exposition and Congress of 1923 attempted to assemble an exhibit of literature relating to petroleum geology and technology. Letters were forwarded to geological surveys and bureaus at home and abroad and a fair start was made toward assembling this exhibit.

In the course of this work a number of interesting letters were received, especially on the attempts to obtain commercial production in foreign lands. Probably one of the most interesting letters is the one from the Secretary of the Department of Mines of Australia, as follows:

> In reply to your letter of the 23rd ultimo, I am to inform you . . . . that there is no evidence as to the existence of oil in this State and . . . . the geological data are not such as to warrant the belief that it is likely to be met with. To date nearly 9000 bores have been put down by this Department to depths of up to 3800 feet without any indication of gas or oil in any of the strata passed through.
>
> Yours obediently,
>
> A. H. MERRIN
>
> *Secretary for Mines, Melbourne, Australia*

It would be very interesting if all of these wells were located on a map, information concerning the distribution and stratigraphic relations of the tests being thus made available to the geological fraternity, especially to those interested in foreign exploration.

JON A. UDDEN

COTTON VALLEY OIL AND GAS FIELD, WEBSTER PARISH, LOUISIANA

The Cotton Valley field is located in T. 21 N., R. 10 W., on a pronounced anticline the top of which is in Section 14, 3 miles east of Cotton Valley, according to the subsurface structure contour map recently published by the Department of Conservation, Shreveport, Louisiana, revised to January 5, 1924, and redrawn as Figure 1. This field is 15 miles east of the Homer field, the same distance north of the Bellevue oil field, 9 miles south of the Sarepta-Shongaloo gas field and 12 miles southeast of the Springhill gas field. It promises to develop into an important gas field and probably into an oil field with oil in the bottom of the gas sand or in a deeper sand. One oil well has already been completed and other wells are making oil.

Cotton Valley development started with the gas well of Webb *et al.* in SW. ¼ NW. ¼, Sec. 13 making 25,000,000 feet of dry gas from the upper part of the Blossom sand, depth 2,556–8 feet, completed August 25, 1922. Later developments were a dry hole in Section 16, a 35,000,000 dry-gas

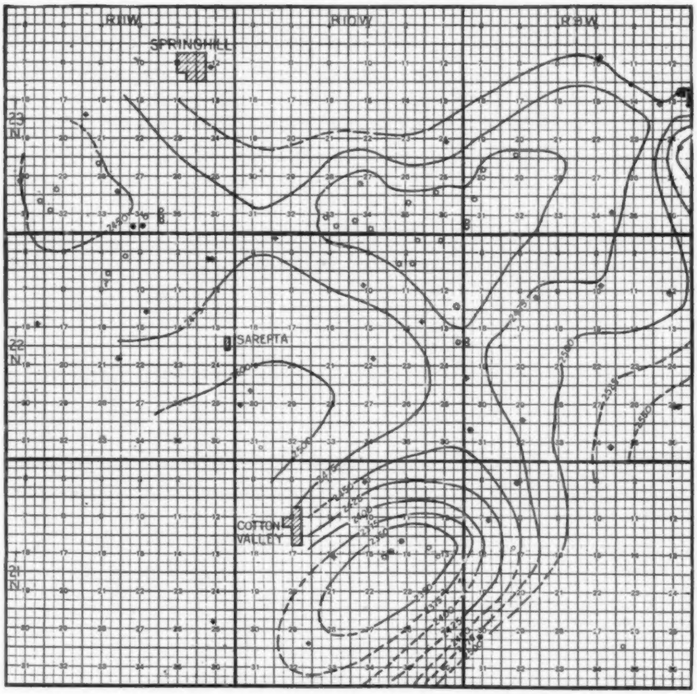

FIG. 1.—Subsurface structure contour map of the North Webster gas fields, redrawn from the map published by the Department of Conservation, State of Louisiana, contoured on the top of the Blossom sand below sea-level. The Cotton Valley field with two oil wells in Section 14 is the dome on the south. The Sarepta-Shongaloo gas field is northeast of Sarepta and the Springhill gas field south of Springhill. The oil wells in Sec. 13, T. 23 N., R. 9 W. are the westernmost in the Haynesville oil field.

well in NE. ¼ SE. ¼, Sec. 15, and a 45,000,000 gas well with a spray of oil in SW. cor., NW. ¼, Sec. 14. The Oil Fields Gas Co. completed a 25,000,000 gas well, a rock pressure of 900 pounds per square inch in NE. ¼ NW. ¼, Sec. 14, December 10, 1923, spraying oil, and this is the discovery

oil well. On February 15, 1924, this well, now owned by the Louisiana Oil Refining Corporation, was flowing 220 barrels daily of $29\frac{1}{2}°$ Baumé gravity oil with a gas pressure of only 40 pounds per square inch. On March 15, it was flowing over 400 barrels through a choke and has produced to that date over 12,000 barrels. A dry-gas well, drilled 24 feet into the sand, has been completed in NW. cor. NE. $\frac{1}{4}$ SW. $\frac{1}{4}$, Sec. 13. The Humble Oil & Refining Co. purchased the discovery gas well and deepened it during February. After deepening the well in March to 2,582 feet, it made 40,000,000 feet of gas with only a spray of oil. On February 21, the Ohio Oil Co. purchased the holdings of the Cotton Valley Syndicate (J. Y. Snyder *et al.*), including the gas well in NE. $\frac{1}{4}$ SE. $\frac{1}{4}$, Sec. 15, for a reported price of $700,000 and an overriding royalty interest. They completed this well in March as a gas well making 18,000,000 cubic feet at a depth of 2,438 feet and the north offset as a gas well making oil. The northeast offset is spraying over 100 barrels a day.

SIDNEY POWERS

SMALLER FORAMINIFERA FOR STRATIGRAPHY

In a recent issue of this publication Dr. Thomas Wayland Vaughan[1] gave the results of a study of American literature on fossil Foraminifera and compared these results with those derived from a study of other groups of organisms. It appeared from the records cited that the species of Foraminifera lived through so many geologic periods that they were of comparatively small value for extensive or useful correlative purposes, but that groups of fossils might be used for recognition of particular strata in a limited region where the sequence was known.

Various formations of the east coast of North America, West Indies, and Panama were selected for comparison. The percentages of recent species of mollusks, corals and bryozoans were determined from the identifications of several paleontologists. The percentages of recent species of Foraminifera were derived from identifications chiefly made by Dr. Joseph A. Cushman. In the face of the figures presented it would seem difficult or impossible, judging by the Foraminifera, to recognize any of the formations considered as belonging to any special geologic age. I do not wish to question the accuracy of the figures given, but there are one or two points to which Dr. Vaughan did not call attention and which

[1] "On the Relative Value of Smaller Foraminifera for the Recognition of Stratigraphic Zones," *Amer. Assoc. Pet. Geol. Bull.*, Vol. 7, No. 5 (Sept.-Oct., 1923), pp. 517-31.

seem to me to deserve consideration by anyone who is endeavoring to evaluate the use of the minute fossils in petroleum development work.

In the first place it is possible that Dr. Cushman has not used the same basis for separating and naming species which was used by the students of other groups. The figures given by Dr. Vaughan differ widely in the percentage of recent mollusks found in the various formations as compared to the percentage of recent corals in the same. We all know that different men differ in their estimation as to what constitutes a species; some will allow a considerable amount of individual variation among specimens while others require absolute identity in the most minute detail before classifying two specimens under the same name. Even the attitude of one man may change in this respect during his lifetime and perhaps some of the species of Foraminifera which Dr. Cushman is alleged to have classed as recent would now not be considered in that light. There seems to be some truth in the often-told story of the single shell which was sent to one of the celebrated paleontologists of Washington three different times and was returned each time under a different name. There is a growing tendency among paleontologists to recognize no species of mollusk found fossilized as being the same as a living species other than in such relatively valueless groups like *Ostrea*. In fact some considerable collections of Miocene and Pliocene mollusks have been described without comparison having been made with recent material at all! There is also a prevailing tendency to recognize no species of mollusk, living or fossil, on the east coast as equivalent to one on the west coast, regardless of similarity. In other words, it seems possible that Dr. Cushman may have taken a more conservative view in the discrimination of his species of Foraminifera than that of workers in other groups. If so, a strict comparison of percentages does not tell all the story. He stated in his paper on the Byram marl[1] that "It will undoubtedly become possible at some future time to distinguish the fossil species of our (East) Coastal Plain and to divide them much more closely and definitely."

In the second place, workers among the Foraminifera have a heritage in the literature which gives no end of trouble. A great many of the known species were described from fossil material, and the publications are entirely inaccessible to the general student. An early English school of microscopists composed chiefly of Carpenter, Parker, Jones, and Brady became so ultra-conservative that the members believed there did not exist in this group of organisms clean-cut species such as occur elsewhere

[1] *U. S. Geological Survey Professional Paper 129-E*, 1922, p. 88.

in nature. They believed that the tests of Foraminifera were so variable in shape and size that the entire group, practically, was homogeneous, and specific names could be given only to certain outstanding variations. The last member of the school was H. B. Brady, who wrote the volumes on Foraminifera in the "Challenger" series of reports.[1] These volumes are by far the most comprehensive ever written on the group and deal with living material dredged in many parts of the ocean. The reports are still accessible, and being fully illustrated have had a profound influence upon the study of the organisms in question. Brady identified a very large number of the living species with those which had been described from fossils at an early date. Modern workers have to review the matter from the beginning, and in a great many cases they are unable to confirm his determinations; instead of the species being so exceedingly plastic they are found to vary within comparatively narrow limits. Dr. Vaughan does not seem to have taken this important fact into consideration in his discussion, but has accepted those species as recent which have been recorded as living, irrespective of the source of the original material.

Thus in his discussion of the Gatun formation (p. 522) he stated that "Forty-four species and varieties are recorded by Cushman, of which 37, or 84 per cent, are still living." On referring to Cushman's Gatun report,[2] a table is found on pages 49–50 giving the distribution of the species discussed. He there gave only 39 species from the Gatun, not 44. Of these 39 seven were described as new. This leaves 32 which had previously been described, and Dr. Vaughan undoubtedly assumed that all of these were Recent. Most of them have been so listed at various times but certainly half, and possibly more, were originally described from fossils. I had hoped to be able to state exactly the number so obtained, but find this to be impossible in the limited time available because of the difficulty in securing the original publications.

It would appear that when the above factors are taken into consideration there is great probability that the percentage of Recent Foraminifera in any given geologic formation may coincide more closely with that of the Mollusca or other group. These remarks are not offered in justification of the use of the smaller fossils for extensive stratigraphic correlation. I do not believe investigations based on the

[1] *Rep. Sci. Res. Exp. Voy. H.M.S.* "Challenger," 1873–78. *Zoölogy*, Vol. 9, text; Vol. 9, pls. 1884.

[2] U. S. National Museum, *Bulletin 103*, 1918.

organisms themselves, irrespective of nomenclature, have proceeded sufficiently far for a broad statement on the subject. In order to condemn the Foraminifera positively as of little value for correlation purposes, it is necessary to take fossilized specimens from any given formation and demonstrate that they are as nearly identical with living specimens as would be required to demonstrate identity of species in the Mollusca. It is not sufficient to accept all identifications in the literature in which living specimens have been called the same as fossils without, in many cases, going back to the original publication of the latter and making a careful check of the determination.

In considering the possible use of the micro-organisms in petroleum development operations, sight should not be lost of the essential facts to be learned. Usually these do not have the slightest bearing on the geologic age of the formation. It is only in prospecting in virgin territory that it will often be found necessary to determine the age of well samples. In developed fields the sequence of major strata is usually well known before many wells are completed, and any information derived from fossils brought up from below is merely corroborative.

The information which the petroleum geologist wishes to derive from a given sample is the relation it bears to the oil sands or certain water zones. In this the micro-organisms have a decided advantage over any others because they occur so often in great abundance and in perfection of preservation. If the succession of sediments in a given field contains a corresponding succession of distinguishable micro-faunas or floras these fossils should be of value in the determination of the position of the drill. Even an exact recurrence or duplication of faunas in two different strata would not invalidate them unless they were contiguous, and this is exceedingly improbable. Dr. Vaughan did not attempt to show, and so far as I am aware no one else has, that the same identical fauna of Foraminifera is found in one vertical section from early Tertiary to Recent. In fact, the literature, and considerable experience in the field, shows that exactly the opposite is true. For instance, no one would hesitate a moment in distinguishing between the Foraminifera of the upper Miocene and the Pliocene of a section in California where both are found. A geologic change sufficient to change the larger organisms, so that a different period can be recognized, usually changes the smaller fauna as much or even more.

Two advantages which the micro-organisms have over the larger fossils in petroleum development need to be mentioned in this connection.

The wide geographic distribution (or lateral in the sediments) of minute animals as contrasted with, say, the Mollusca is decidedly advantageous because in a given area there is much greater opportunity to recognize the same stratum at two different points. Moreover, the incomparable vertical sections furnished the microscopist from deep oil wells are such as the student of molluscan paleontology can never hope to secure; to do so it would be necessary for him to sink a colossal shaft to an equal depth, the diameter bearing the same ratio to the diameter of the well as the average foraminifer bears to the average mollusk.

G. DALLAS HANNA

SAN FRANCISCO, CALIFORNIA
December 13, 1923

ERRATUM

In the Geological Note on "Gas Near Fort Collins, Colorado," by Max W. Ball, published in the *Bulletin* of January-February, 1924, pages 79-87, the following dates should appear on page 87: The date at the end of the paper itself should be *November 20, 1923;* the date under "Further Note on Wellington" should be *December 12, 1923;* and the date under "Still Further Note on Wellington" should be *December 27, 1923.*

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[1] Published by permission of Acting Director, U. S. Geological Survey.

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BERTRAND L. JOHNSON[1]

[1] Assisted by Miss L. M. Jones and Miss M. F. McShea.

THE ASSOCIATION ROUND TABLE

MEMBERSHIP APPLICATIONS APPROVED FOR PUBLICATION

The Executive Committee has approved for publication the names of the following applicants for membership in the Association. This publication does not constitute an election, but places the names before the membership at large. In case any member has information bearing on the qualifications of these applicants, please send it promptly to Charles E. Decker, Norman, Oklahoma.

(Names of sponsors are placed beneath the name of each applicant.)

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William G. Gallagher, Jr., Fort Collins, Colorado
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Raymond H. Goodrich, Houston, Texas
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Bruce Whitcomb, Groesbeck, Texas
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Louis D. Wosk, Golden, Colorado
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FOR TRANSFER FROM ASSOCIATE TO FULL MEMBERSHIP

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AT HOME AND ABROAD

CURRENT NEWS AND PERSONAL ITEMS OF THE PROFESSION

HENRY HINDS, whose permanent mailing address is 1153 Laurel Avenue, St. Paul, Minnesota, is now president and manager of the Venezuela Oil Corporation, with headquarters in Caracas, Venezuela.

WILLIAM S. W. KEW, associate editor of the Bulletin for the Pacific Coast, has resigned from the United States Geological Survey. After February 10, he is to be associated with MR. HOYT S. GALE in work in California, with headquarters in Los Angeles.

SIDNEY POWERS, able wildcat geologist, is sponsor for a well in Cass County, Nebraska, where most geologists tell him there is no oil. It is easy to condemn an area, but creditable to find oil in a region generally condemned. However, the oil is not yet found.

FREDERICK G. CLAPP is engaged in geological work in Australia.

RAYMOND C. MOORE recently talked before the Tulsa Geological Society, the Okmulgee Geological Society, and the University of Oklahoma on his boat trip last summer through the Grand Canyon of Colorado River. Motion pictures were shown.

M. M. VALERIUS has raised high hopes in many Kansas breasts by the success of his Russell county test.

On January 8 E. DEGOLYER, C. W. WASHBURNE, and I. N. KNAPP addressed the Washington section of the American Institute of Mining and Metallurgical Engineers at Washington.

HUGH D. MISER, who for some six months has been engaged in work on the new geological map of Oklahoma, finished his work in Tulsa on this map in the latter part of February and has returned to Washington.

WINTHROP P. HAYNES, chief geologist for the Standard Oil Company of New Jersey in Europe with offices in Paris, was in New York during a part of January and February. After a short stay in France, he is now en route to Bombay, Singapore, and the Dutch East Indies, where he will spend some months.

ROBERT H. and VIRGIL O. WOOD with GEORGE I. MCFERRON have recently transferred their offices from the Daniel Building to 302 Commercial Building in Tulsa.

WM. KENNEDY, chief geologist for the Lone Star Gas Company of Dallas, has been under the weather for some time, but is again able to be in his office.

J. W. BOSTICK, formerly geologist for the Kansas and Gulf, is headquartering in Dallas for a few months while looking over north and east Texas developments.

ROBERT T. HILL gave a very interesting illustrated talk on the Canyon of the Rio Grande at a recent meeting of the Southwestern Geological Society in Dallas. Following this discussion the Society elected CHESTER A. HAMMILL president and HEATH M. ROBINSON secretary of the organization for 1924.

FREDERICK H. LAHEE, chief geologist of the Sun Oil Company, has been spending several months in South America.

CHARLES H. ROW is acting chief geologist in the offices at Dallas.

CHARLES M. RATH, secretary of the Rocky Mountain Association of Petroleum Geologists, reports that a good number of geologists from Denver are planning to attend the Houston meeting. He also states that the local association has never contemplated the publication of a journal of any kind, contrary to rumors which seem to have circulated.

The Rocky Mountain Association has had the following luncheons:

January 3. An extemporaneous discussion of the "Productive Sand in the Wellington Dome, Colorado," led by C. J. HARES, R. C. COFFIN, JUNIUS HENDERSON, R. D. GEORGE, and CARROLL H. WEGEMANN.

January 17. A paper on "The Origin of Oil," by PROFESSOR F. M. VAN TUYL, Colorado School of Mines.

February 7. An address on the economic features of the "Federal Oil Land Leasing System," by CLAY TALLMAN, former Commissioner of the General Land Office.

February 21. A paper entitled "Production, Marketing, and Economics of Natural Gas," by ERNEST MARQUARDT, vice-president of the New York Oil Company.

WALLACE LEE made a visit to Denver last week on his way to St. Louis. MR. LEE has just returned from Siam, where he spent two years making a reconnaissance study of the oil possibilities for His Imperial Majesty, the King, of Siam. After his assignment was completed, MR. LEE visited other parts of the Far East, including China, Japan, and the Dutch East Indies, also stopping at the Hawaiian Islands on his return.

A letter from HAROLD W. C. PROMMELL gives some very interesting information and experiences in connection with geologic work in Brazil. He sums up by stating, "This is indeed an interesting country, but if Kansas and Wyoming have been called the geologist's paradise, then Brazil rightly deserves the name of the geologist's hell."

F. M. VAN TUYL, Colorado School of Mines, is giving a popular course of lectures on oil geology in connection with the Institute of Technology of the Denver Y.M.C.A. MAX W. BALL, PAUL C. WHITNEY, and E. RUSSELL LLOYD collaborated with PROFESSOR VAN TUYL in outlining the course of lectures.

F. F. HINTZE, formerly chief geologist for the Producers and Refiners Corporation, since the consolidation of that company with the Prairie Oil and Gas Company, has charge of geologic work for the Prairie, with headquarters in Denver.

JAMES M. DOUGLAS, chief geologist in the Rocky Mountain region for the Union Oil Company of California, has moved his office from Casper to Fort Collins. MR. DOUGLAS is the proud father of a baby daughter.

WALTER ENGLISH has recently arrived in Denver to be in charge of a geologic force for the Standard Oil Company of California, with offices in the Patterson Building.

W. B. HEROY, geologist for the Sinclair Oil Company, with headquarters in New York, spent some time in Denver and vicinity during the early part of January.

HENRY J. PACKARD has been made chief geologist for the Mutual Oil Company, with headquarters in Denver. MR. PACKARD reports the arrival of a baby daughter at his home.

CARROLL H. WEGEMANN, chief geologist for the Midwest Refining Company, has recently returned from a visit to Washington and Baltimore.

THOMAS S. HARRISON, consulting geologist in Denver, and MRS. HARRISON, spent several weeks in February and March on a pleasure trip to the Hawaiian Islands.

MAX W. BALL left Denver March 1 on a business trip to New York to be gone about two weeks.

JAMES H. HANCE was in Washington, D.C., during the early part of March.

CHARLES LAWRENCE BAKER has joined the geological staff of the Indian Territory Illuminating Oil Co., Bartlesville, Oklahoma.

WILLARD W. CUTLER spent part of February in Washington, D.C.

E. CALL BROWN has gone to New Zealand to study the oil geology of the island for the New Zealand government.

JOSEPH T. SINGEWALD, JR., is in South America. His classes at Johns Hopkins University are being carried by a group of men from the Geological Survey, including D. F. HEWETT, H. G. FERGUSON, E. SAMPSON, F. L. HESS, and K. C. HEALD.

ALAN M. BATEMAN, of Yale University, was in Washington, D.C., early in March on business connected with *Economic Geology*, of which he is editor.

W. W. Rubey, M. N. Bramlette, and N. W. Bass, of the United States Geological Survey, are in Kansas where the U.S.G.S. is co-operating with the Kansas Geological Survey on a number of projects.

CURRENT NEWS AND PERSONAL ITEMS OF THE PROFESSION

L. H. Freedman, geologist of the Snowden & McSweeney Company, is watching developments at Big Creek, Fort Bend County, Texas. Big Creek is the salt dome discovered by the Gulf Production Company and the Snowden & McSweeney Company in 1922.

L. P. Garrett, who resigned his position as a vice-president of the Gulf Production Company several months ago, has taken over the interests of Lee Hager in the Tidewater Oil Company, and has assumed the management of this concern which is principally engaged in the acquisition of Gulf Coast royalties.

F. M. Hutchinson has resigned as president of the Higgins Oil & Fuel Company in order to look after his personal interests.

Edgar Kraus, geologist with the Atlantic Oil Producing Company, has been transformed from Houston to Enid, Oklahoma.

J. Elmer Thomas, of Chicago, Los Angeles, and Palm Beach, was in Houston in February.

F. E. Vaughan, geologist of the Roxana Petroleum Corporation with Houston headquarters, is in charge of the investigations that the Roxana is now conducting on the Gulf Coast with the torsion balance.

Donald C. Barton, of the Rycade Oil Corporation, also has a "salt dome indicator." It has been suggested that the Roxana and the Rycade put on a "wiggle-stick field day" during the Houston meeting.

Grady Kirby is geologist for the Gulf Production Company with headquarters in the Bedell Building, San Antonio, Texas.

Thomas J. Galbraith is with the California Standard Oil Company doing geological work in Ecuador, and will probably return to this country in the fall.

E. P. Rothrock is teaching at the University of South Dakota, and is doing field work in Pleistocene geology during the vacations.

H. D. Miser, who has been doing some field work in Oklahoma for a map of the state to be published by the U. S. Geological Survey, has returned to Washington to complete the office work on this map.

C. L. Dake, professor of geology at the Missouri School of Mines and Metallurgy, spoke before the Tulsa Geological Society, Tulsa, Oklahoma, February 16, on the subject of "The Ozark Uplift."

C. B. OSBORNE and E. G. SINCLAIR recently testified as expert witnesses before the Federal Court at Portland, Oregon.

The faith and persistence of W E. RENNIE were largely responsible for the recent discovery of oil at Hamilton Dome, Craig County, Colorado.

ROSWELL H. JOHNSON is engaged with O. H. BLACKWOOD, a physicist, in research on the mathematics and physics of the Bradford water-lime situation for the Forest Oil Company, of Bradford, Pennsylvania.

ROSWELL H. JOHNSON spoke recently to the Petroleum Club of Pittsburgh on the navy oil reserves, and will give some lectures this spring at the Massachusetts Institute of Technology on petroleum technology.

PHILIP S. SCHOENECK has recently returned from Angola, Africa, where he had been working as a geologist for the Sinclair Consolidated Oil Company.

O. B. WENDELN has been appointed chemist for the refinery at Cabin Creek, West Virginia, of the Pure Oil Company.

M. S. JOHNSON has left the Pennsylvania Geological and Topographical Survey to resume study at Harvard University. His stratum map of the north half of the Pittsburgh quadrangle has been published recently by the Pennsylvania Survey.

L. G. HUNTLEY is doing field work in Venezuela.

WALTER E. HOPPER recently appeared as an expert witness on the value of some Louisiana properties at a court hearing at Waynesburg, Pennsylvania.

WILLIAM GRETZINGER, who for some time has been in Ecuador, is returning to Pittsburgh, Pennsylvania.

E. FAISON DIXON has returned to Europe. He is working in Spain and Southern France.

EDWIN B. HOPKINS is still commuting between New York City and Venezuela.

A. C. VEATCH sailed for somewhere four weeks ago on a "three weeks' trip" and may get back in twenty weeks.

Members called to testify in the Teapot Dome inquiry include F. G. CLAPP, K. C. HEALD, J. O. LEWIS, GEORGE OTIS SMITH, and CHESTER W. WASHBURNE.

G. A. WARING has completed his work in Trinidad, British West Indies, for the Whitehall Petroleum Corporation, Ltd., and is now with the Margay Oil Corporation, Tulsa, Oklahoma.

K. C. HEALD, chief of the oil and gas section of the U.S. Geological Survey, is giving a course of twelve lectures at Johns Hopkins University.

W. W. WUBEY, who has recently been at Yale University, will be engaged in geological studies in western Kansas for the U. S. Geological Survey and the State Geological Survey of Kansas.